JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CX. AUGUST, 1880. No. 2.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

THE LIMITATIONS OF THE STEAM ENGINE.

By WILLIAM DENNIS MARKS, Ph.B., C.E.,

Whitney Professor of Dynamical Engineering, University of Pennsylvania.

Perhaps there is no more unsafe proceeding in science than to attempt to predict the limitation of the development of any of its results. Yet the theory of the steam engine has so far been developed as to seem to permit us to mark out the boundaries of its progress with tolerable accuracy.

At least, we trust that a full criticism of its present deficiencies, and a deduction of its limitations from known laws, will interest such of our readers as are engaged in the improvement of this machine, to which our civilization is more indebted for its advancement than to any other one thing.

In this article we will consider the steam engine alone, as it is in no wise responsible for the economy of the boiler which supplies the steam, or for the losses incurred in conveying the steam from the boiler to the engine.

The boiler should be considered apart from the engine, and it is well to incidentally remark here that the performances of the best types of boiler leave but little room for improvement so far as evaporation is concerned.

It is rather in the utilization of the steam after it reaches the engine that we must look for progress, and in this point, we take it, lies the value of a thorough investigation of the machine itself.

The well-known formula for the horse-power of a steam engine* contains three factors, which can be varied at will: the mean effective pressure, the volume of the cylinder, and the number of strokes per minute.

Concentration of power in a small space is the greatest attribute of the steam engine; it is its power to concentrate the strength of thousands of horses in the space of an ordinary room that renders the steam engine so useful and indispensable to us.

For this reason we cannot go on increasing the volume of the steam cylinder indefinitely without a proportionate increase in power, and it is only necessary to remark to mathematicians, with regard to the proproportions of the cylinder, that that cylinder whose stroke equals its diameter contains the maximum of volume with the minimum of condensation surface.

The importance of reducing condensation surface is becoming more and more appreciated among engineers, and shortening the stroke will prove less of a bugbear when the laws of inertia, as applied to the reciprocating parts of a steam engine, are better understood.

Shortening the stroke has the further advantages of shortening the space passed over by the piston head during a given number of strokes, and consequently of reducing the wear on the piston head, as well as of rendering the engine more compact for a given power.

The following formula gives for any assumed horse-power, mean effective pressure, and number of strokes per minute, the required common diameter and stroke of cylinder, *in inches:*

$$d = 79{\cdot}59 \sqrt[3]{\frac{(HP)}{N\,P}} \dagger$$

Concentration being attained, the next important consideration that arises is *economy of steam*, and this is the battle ground upon which the struggle for supremacy among our engine builders is to-day

---

* $\frac{P\,L\,A\,N}{33000} = (HP)$. In which P = mean effective pressure per square inch, L = length of stroke in feet, A = area of piston in square inches, N = number of strokes per minute, (HP) = indicated horse-powers, $\frac{A\,L}{144} = V$ = volume of cylinder.

† *The Relative Proportions of the Steam Engine*, p. 16. Marks.

being practically fought out, while the physicists are quite as hotly engaged in a dispute as to the relative theoretical merits of steam, hot air, and electric engines, into which we will not enter.

Practically, we think that, as far as the steam engine is concerned, the impossibility of supplying to the steam in the cylinder any appreciable amount of heat by means of steam or hot air jackets is acknowledged by all, and the jacket is only expected to keep the cylinder warm, and prevent it from abstracting heat from the steam inside the cylinder.

The jacket proving imperfect, we must find other means for preventing condensation by cooling, and they are these: Diminution of condensation surface, as already stated above, and shortening of the duration of the time for condensation, which means an increase in the number of strokes of the piston. The effect upon the structure of the engine of increased rotative speed is not injurious to the engine, as so positively stated by many engineers; but, if attempted, rapid speed requires a far greater knowledge of the dynamics of the steam engine than has as yet been applied to it by many constructors, and will almost inevitably shake to pieces a faultily designed structure.

The length of the crank pin and shaft bearings must also increase directly with the number of revolutions made, while their diameter, within ordinary limits as to pressure and speed, has no appreciable effect upon the heating of the bearing; but when we consider the practical fact, that the eccentrics, possibly because of greater speed of rubbing surfaces, are always sources of large frictional losses, it would seem best to make the diameters of all bearing journals just as small as the pressures allowable upon the surfaces of contact will permit. Much yet remains to be determined with regard to the laws controlling bearings. A very interesting work has been published on *Friction and Lubrication*, by Professor Thurston, but it is to be regretted that he has formulated the results of his experiments with so much positiveness, as other and careful experimenters have found it difficult to obtain results which clearly verify each other.

He has shown conclusively that the coefficient of friction is much affected and reduced by the state of the rubbing surfaces, by the method of lubrication, and by the quality of the lubricant.

Perfect, almost mirror-like, surfaces reduce the coefficient of friction far below the 3 to 5 per cent. formerly stated by Morin as a minimum, provided a continuous lubricating apparatus is used with good

sperm oil, and it will be found that a costly lubricant such as sperm oil is cheapest where care is exercised not to waste in its application.*

The important influence of the number of turns upon the length of bearings has not been clearly enough understood to prevent accidents from heating of the crank pins and bearings, which is one of the most annoying mishaps which can befall an engine, and at times requires the utmost vigilance of the engineer for its prevention.

The great difficulty attendant upon making bearing and shaft press uniformly throughout the length of the journal has almost forced the use of Babbitt or soft metal for high speed engines, and where proper care is taken in proportioning the results have justified its use.

Crank pins shrunk in by heating the crank, are apt to be out of truth, no matter how carefully the work has been done, as heat is apt to warp the crank.

Pins should be forced in cold, or the crank and pin be forged in one piece as in the case of most small double cranks.

High rotative speed, while increasing the power of the steam engine, also renders it more compact and diminishes the weight of the fly-wheel necessary to obtain regularity of speed.

Rotative speed has, however, its limitations, independently of the trouble sometimes caused by the heating of bearings.

For instance, it can be shown that if the safe stress in tension upon cast iron equals 1800 pounds per square inch, that a cast iron ring can be revolved safely at a maximum lineal speed of 8000 feet per minute, or thereabouts, which at once places a limitation upon the rotative speed of the fly-wheel, and demands reduction of its diameter as the rotative speed is increased.

---

* Let l = the length of the crank pin, in inches.
" L = " stroke, in feet.
" (HP) = the indicated horse-power.

Then, for marine propellor engines, a practical formula, giving safe lengths, would be

$$l = 0{\cdot}622 \frac{(HP)}{L}$$

One-fourth of this length will serve safely for side-wheel or stationary engines.

For locomotive engines practice seems to prove that $l = {\cdot}013\ d^2$ is a safe value, in which d = diameter of the steam cylinder, in inches.

For crank shaft bearings, letting R = the whole maximum weight on bearings, and N = the number of strokes per minute, we have $l = {\cdot}000005\ R\ N$.

Let N = the number of revolutions per minute.
" D = the diameter of cast iron ring, in feet.
We have

$$\pi D N = 8000$$

or

$$D N = 2546.$$

This formula would limit the diameter of the fly-wheel of a pair of engines, to make 600 revolutions per minute, lately proposed by the distinguished engineer, Mr. Chas. T. Porter, to about 4 feet.

Of course, as the tensile strength of the material of which the fly-wheel is made is increased, the lineal speed at which it can be driven is increased.

If we take 5000 pounds per square inch as the safe tensile strength of the steel tire of a locomotive, we find its lineal speed to be limited to about $2\frac{1}{2}$ miles per minute, or 150 miles per hour, and it only remains for our engineers to provide boiler capacity and road bed adapted to such speeds, in order that they may be realized by a properly constructed locomotive.

This speed would shorten the time between New York and Philadelphia to 36 minutes.

High rotative speed necessitates special precautions as to the weight of the reciprocating parts.

If we impose the condition that the initial and final stresses upon the crank pin be equal, we must make the centrifugal force of the reciprocating parts (piston, piston rod, cross head and connecting rod), supposed to be concentrated at the crank pin, equal to half the difference of the initial and final steam pressures upon the whole piston head.

High rotative speed has also demanded a change in the form of the connecting rod, which was formerly largest at its mid-length, but has of late years been made largest at the crank pin end; a consideration of the stress upon it, due to its own inertia, would place the point of greatest stress at 0·578 of its length from the cross head end, but the stresses due to the twisting of the crank pin in its boxes recommends as a measure of safety that the rod be made largest at the crank pin neck, and tapered down from that to the cross head.

In a properly proportioned engine, of any assumed horse-power, the *only* method of reducing the weight of the moving parts is to increase the rotative velocity; lengthening the stroke will not do it.

The points of interest with regard to the volume of the steam cylin-

der and the rotative speed of the engine having been touched upon, there remains to be considered the mean effective pressure of the steam.

In the JOURNAL OF THE FRANKLIN INSTITUTE for June, 1880, the writer has shown, under the assumption that the steam expansion curve is an equilateral hyperbola, that the most economical point of cut-off for steam engines is determined by dividing the absolute back pressure by the absolute initial pressure of the steam.

Indicators do not give such curves, even if in perfect order, unless the steam is a little wet; but the approximation is sufficiently close for all practical purposes.

A more accurate way would be to say that the most economical point of cut-off is attained when the final steam pressure equals the back pressure; but our first statement is more convenient in form and will serve our purpose, with all the practical accuracy necessary.

Let P = the mean effective pressure of steam in pounds per square inch.

Let P_b = the initial absolute pressure of steam in pounds per square inch.

Let B = the back absolute pressure on piston in pounds per square inch.

Let e = the fractional part of the stroke at which the steam is cut off.

Let V = the volume of the steam cylinder in cubic feet.

Then we have

$$P = e\,P_b \left[1 + \text{nat. log. } \frac{1}{e}\right] - B$$

Let (HP) = the indicated horse-power.

" S = the specific volume of the steam for a pressure, P_b.

" W = the weight of water used per horse-power.

We have

$$(HP) = \frac{P\,L\,A\,N}{33000}$$

in which L = the length of stroke in feet.

N = the number of strokes per minute.

A = the area of the piston head in square inches.

Therefore

$$(HP) = \frac{\left\{ e P_b \left[1 + \text{nat. log. } \frac{1}{e} \right] - B \right\} V N}{33000} \times 144$$

since $144\ V = L\ A$.

The quantity of water used during one minute is

$$62\tfrac{1}{2}\ \frac{e\ V\ N}{S}$$

$62\frac{1}{2}$ pounds being taken as the weight of one cubic foot of water.

Therefore, the weight of water used per horse-power is

$$W = \frac{62\tfrac{1}{2}\ \dfrac{e\ V\ N}{S}}{\dfrac{144}{33000}\left\{ e P_b \left[1 + \text{nat. log. } \dfrac{1}{e} \right] - B \right\} V N} = \frac{14323\ e}{S \left\{ e P_b \left[1 + \text{nat. log. } \dfrac{1}{e} \right] - B \right\}}$$

If in this last formula we substitute $\frac{B}{P_b}$ for e, we obtain the theoretical minimum quantity of water to be evaporated per horse-power, and

$$W = \frac{14323}{P_b S. \text{ nat. log. } \dfrac{P_b}{B}} = \frac{6220{\cdot}3}{P_b S \log. \dfrac{P_b}{B}}$$

For one horse-power per hour we would have, multiplying by 60,

$$60\ W = \frac{373218}{P_b S \log. \dfrac{P_b}{B}}$$

As, for instance, for a non-condensing engine having a gauge pressure of 45 pounds, and cutting off at $\frac{1}{4}$ the stroke, we find the minimum limit of evaporation of water required to be about 24 pounds of water per horse-power per hour.

Mr. Charles E. Emery has experimentally realized as low as 39 pounds of water per horse-power per hour with the given pressure, in small non-condensing engines.

If, in the last formula, we regard the product of the pressure, and the specific volume, $P_b\ S$, as constant, which it is with a considerable

degree of approximation, we observe that the economy varies directly as the log. $\frac{P_b}{B}$, showing that both Watt and Oliver Evans were partially right in their attempts to increase the economy of the steam engine. Watt was right in perfecting more and more the vacuum obtained, and Evans in increasing the steam pressure at the boiler. Neither of them were wholly astray, but were soon met and their progress stopped by the slow increase of the economy beyond certain limits, and by the practical difficulties arising in the pursuit of a partially apprehended law.

It is evident that we are limited as to the steam pressure, and that a great increase of that, or a great decrease of back pressure, by reason of more perfect vacuums, will render the point of cut-off so early, and the mean effective pressure so low, that the necessary increase of volume in the steam cylinder will prevent that compactness and concentration of power so desirable in the steam engine; and, although it has already been shown that high rotative speed aids in rendering the engine compact, we are also limited in that direction.

Regularity of speed is an imperative condition in all engines used to drive high-speeded machinery; under such circumstances, regularity becomes the first requisite, and to it all other considerations must be subordinated.

Mr. G. H. Corliss, with his automatic cut-off engine, was the first to satisfactorily solve this problem.

With a constant steam pressure and a constant load, an engine will run, under the control of a throttling governor, with an approximation to regularity determined by the sensitiveness of the governor. With a throttling governor every change of the steam pressure, every change in the load causes a change in the speed of the engine, no matter how well proportioned it may be.

The laws regulating the centrifugal governor are such as to prevent it from ever becoming a very perfect mechanism, for the engine *and governor* must go fast in order to go slow, and *vice versa*. With an automatic cut-off governor, the speed will be held with regularity under all steam pressures and loads within its capacity, the approximation to perfection attained being determined by the proportions of the fly-wheel and the sensitiveness of the governor.

Governors in which the inertia of the balls is utilized to check any attempted change of speed, without an appreciable change of speed in

the governor itself, will ultimately supersede the centrifugal governor, which is full of radical defects.

Valve motions, actuated by a weight or spring released automatically by the governor, are comparatively so slow in their motions as to prevent high rotative speeds and short strokes. This form of valve motion has been elaborated with great skill and ingenuity on such engines as the Corliss, Harris-Corliss, Reynolds-Corliss, Wheelock's and Brown, which, so long as long stroke and slow rotation is adhered to, leave but little to be desired on the score of regularity of motion or perfection of workmanship.

To a different class belong the Porter-Allen and the Buckeye engines; in these engines, which are the exponents of high rotative speeds and short strokes, the cut-off of the engine is actuated by means of a link or an eccentric, whose position is regulated by means of a centrifugal governor, and, whatever the speed, the valves must keep pace with the engine in its motions.

A large number of valve motions are in use on the various forms of locomotive, marine and stationary engines, throughout the civilized world, and it is perhaps worth our while to practically note the important points of some of the older forms.

The plain hollowed slide valve is the most commonly used on the rougher forms of engines, because of its simplicity; as, however, the earliest point at which it can cut off steam without choking the exhaust is about $\frac{3}{4}$ of the stroke, it is not economical with the high pressures of the present day or with the vacuums ordinarily attained in condensing engines.

When a reversing gear is used, the Stephenson link motion is commonly used, where simplicity of mechanism rather than economy of steam is a point to be gained.

With open rods it has a variable lead, decreasing from the dead point; with crossed rods it has a variable lead, increasing from the dead point.

For crossed rods, the position of the piston is nearly constant at the opening of the steam ports; this is a decided advantage. Crossed rods permit a slightly greater length of eccentric rods.

Fastening the link to the ends of the eccentric rods, at a point behind the centre line of the link, as is usually done in American practice, introduces irregularities into the point of cut-off, but does not affect the lead.

When the ends of the eccentric rods are fastened to the link, at points on the centre line of the link, this error does not occur, but larger eccentrics are required, which are sometimes inconvenient.

The mode of suspension of the link is far more important than is usually supposed, as imperfect suspension not only introduces serious errors in the valve motion, but also affects the durability of the construction, by producing excessive slip in the block.

Where a constant lead is desired, using different angles of advance for the two eccentrics will produce a constant lead in one direction of motion, but ruins the action of the valve motion in the opposite direction.

The Gooch link motion is difficult to fit into an engine, because of the distance required between the centre of the crank shaft and the end of the radius rod; it is very easy to handle, and should therefore be used where frequent reversing is necessary, as in the cases of yard locomotives and hoisting engines, even though requiring considerable trouble to fit in.

If a constant lead be a great advantage, this link motion has this advantage. The suspension link for the link proper should be made as long as possible, and the suspension link for the radius rod should be attached as closely as possible to the link block. The tumbling shaft should be placed on the opposite side of the link from the crank shaft.

Allan's link motion, having a straight link, can be more easily fitted up than motions having a curved link; it has all the disadvantages of the Gooch link motion, but, unlike it, has not a constant lead, and has a greater number of parts. Particular attention must be paid to the relative lengths of the tumbling shaft arms for simultaneously raising and lowering the link and radius rod. The Allan link motion does not handle as easily as the Gooch.

Heusinger von Waldegg's link motion is the easiest of all to handle; it can be so arranged as to have very little slip in the block, but cannot be easily attached to all forms of crosshead.

It is the simplest reversing gear yet mentioned, and has a constant lead.

Pius Fink's link motion is the simplest reversing gear in existence which at the same time can be adjusted as a cut-off; it has a constant lead, but a limited range of action, and in this point is inferior to all

the others, as well as being irregular in its variation from its calculated positions.

However, if carefully designed it will do good work, and is very easy to handle and very durable.

The fact that it is impossible to avoid choking the exhaust, and the consequent compression of the steam, thereby reducing the power of the steam engine whenever the attempt is made to cut off early in the stroke with a single valve has led engineers to devise double valve motions which will effect an early cut off of the steam, independently of the motion of the hollow of the slide valve relatively to the exhaust.

To this type belong the valve motions of the Porter-Allen and Buckeye engines, both of which show a wide range of action for motion in one direction, and great simplicity of structure.

The Gonzenbach link motion, with its double steam chest and excessively complicated outside gear, is now almost obsolete; it will not cut off sharply and well, except for very early points, and that, too, only for motion in one direction, and when properly arranged for motion in one direction gives a double admission of steam for motion in the opposite direction; it is difficult to handle, and its complication renders it very liable to break down.

The Polonceau link motion, while it has not the double steam chest or as much complication in its outside valve gear, cannot cut off steam later than $\frac{1}{3}$ of the stroke, and is therefore not very well adapted to general locomotive use where economy is sacrificed to concentration of power.

It is not very difficult to handle, but, like the Gooch, presents some difficulty in adapting to the narrow limits offered by a locomotive.

Meyer's link motion seems to have met with the greatest favor from builders of marine and stationary engines, as it presents a wide range for motion in one direction, and a greater range when used as a reversing motion than any of the others.

The screws which move the expansion blocks are liable to rust or wear, and cause trouble; the expansion valve should have separate eccentrics to work best; it is intricate in its construction, and liable to break down.

It is also difficult to handle, and absorbs much power unless the distribution valve is balanced.

An ingenious modification of the Meyer valve motion is the Ryder

cut-off, in which a cylindrical expansion valve, whose edges approach each other after the manner of an isosceles triangle wrapped around a cylinder, is moved around its axis by means of the governor, so as to have the same effect as that of increasng or decreasing the distance between the expansion blocks of the Meyer cut-off.

In order that we may make ourselves clearly understood, we recapitulate.

A really good steam engine should possess the following qualities: Concentration of power, economy of steam, regularity of speed, simplicity of design and durability of construction.

We have endeavored to mark the limitations of the first three attributes of a good engine; the last two must be worked out in the shop.

We are, perhaps, too bold in our prediction, but it seems to us that the engine of the future will have a cylinder whose stroke is equal to its diameter, its speed will be limited by the tensile strength of its revolving parts, its bearings will be of great length, its cut-off will be determined, approximately at least, by the ratio of the back pressure to the initial pressure, its valve motion will be rigidly in connection with the crank shaft, its reciprocating parts will be so proportioned as to put a nearly constant pressure on the crank pin, its flywheel, if it has one, will be proportioned so as not to admit of more than a predetermined variation of speed during one stroke, its governor will no longer be centrifugal but a revolving pendulum, almost isochronous, and holding the engine, with all necessary approximation, within fixed limitations, to a constant speed.

Philadelphia, June 25th, 1880.

Influence of Winds on the Barometer.—When a balloon is borne along by a rapid current calculations of its altitude are not trustworthy. When the velocity is very great, the error may be as great as one-third of the estimated height. Kaemtz, from the study of barometric observations at Paris, Zurich, Berlin and Halle, found that the readings were affected by the direction of the wind. Montigny has discovered a similar influence at other stations, but at Brussels and Namur the influence is directly opposite to that at Antwerp. —*Les Mondes.* C.

ECONOMICAL CUT-OFF IN STEAM ENGINES.

By S. W. Robinson
Of Department of Mechanical Engineering, Ohio State University.

Theoretically the most economical cut-off is readily seen to be that by which the steam at the instant of release has, in the particular cylinder, and under the particular conditions, no capacity for developing further work.

In a cylinder of indefinite extent, having one fixed head and a moving piston between which steam has been admitted to a certain point, then cut off and expanded, the best point theoretically, at which to release the steam will be where the pressure has fallen by expansion to the back pressure. This is evident from the fact that up to this point there is an effective pressure upon the piston to urge it forward, while beyond this point the effective pressure is backward, or prejudicial. An indicator card taken from an engine working under these conditions will have a sharp point at the end, or termination of stroke. If the atmosphere is the back pressure, as in case of non-condensing engines, then the release occurs where the expansion pressure equals one atmosphere. In condensing engines it is where the expansion pressure equals the pressure of the condenser, where the back pressure is zero, if possible, it is where the volume of expansion is infinite. For this latter case the above ideal cylinder must be of infinite length.

For all the above cases, the ratio of expansion is equal the pressure of admission divided by the back pressure, where Mariotte's law of expansion holds; since, by this law, initial pressure $\times$ initial volume = final pressure $\times$ final volume. Or,

$$\frac{\text{initial pressure}}{\text{final pressure}} = \frac{\text{final volume}}{\text{initial volume}} = \text{ratio of expansion.}$$

This result agrees with that obtained analytically by Professor Wm. D. Marks in the June number of this Journal, where the simple rule for finding the most economical point of cut-off, *stated in words as that by which the terminal pressure must equal the back pressure,* was looked for without success. According to this rule, the indicator card shows at a glance when the specified adjustment is realized.

This adjustment of the cut-off is pretty generally accepted by engineers as the best *theoretically*. But in actual steam engine practice the adjustment will be quite different, for several reasons, such as excessive size of cylinder, causing loss by radiation of heat and cooling by expansion, friction by mechanism, undue strains of parts or increased piston speed, etc. For instance, the size of the crank pin enters into the problem. In practice, the indicator diagram from an engine running under the most favorable conditions, or with the most economical practical cut-off, should show its narrow end cut square off with some considerable breadth, instead of being absolutely sharp; and what breadth it should have is a matter not easily determined. To illustrate, take an example of a non-condensing engine working under 90 pounds absolute pressure of admission per square inch, cutting off at one-fourth the stroke. The terminal pressure will be 7½ pounds above the atmosphere, Mariotte's expansion; but if the cylinder were 50 per cent. longer, the terminal pressure would be just the atmospheric, or that required by the solution given by Professor Marks. The gain in work done per stroke, for the 50 per cent. longer cylinder, will however be, as found by calculation, less than 4 per cent. of the work done without the 50 per cent. added.

To save this 4 per cent., the engine, for a given establishment, would require to be one-half larger, making the same number of strokes per minute. Or, if the number of strokes diminish with increase of size, it would need to be more than a-half larger. Aside from the considerations of greater loss of heat by radiation, cooling of steam, friction, etc., there comes the interest to be paid on the additional investment required in the larger engine. In the light of considerations like the above, which must be familiar to professional as well as practical engineers, it would seem that the qualifications needed to the last sentence in Professor Marks' article must, through some hurry or otherwise, have been overlooked, but which, it is hoped, will be fully supplied in the article promised soon to follow.

French Railway Union.—The French railway companies have decided to establish a common tariff for all the districts of France. The plan which they propose to adopt will enable all freighters to calculate, before shipment, the charges upon packages of every description.—*Chron. Indust.* C.

PROGRESS OF THE DEPHOSPHORIZATION OF IRON.

(CONTINUED.)

By F. GAUTIER.

Read before the Society of Civil Engineers of Paris, January 9th, 1880.
Translated by CHAS. E. BILLIN.

EXPERIMENTS IN AUSTRIA.—The works of Witkowitz, situated in Moravia on the prolongment of the coal basin of Silesia, found it difficult to procure ores of sufficient purity for treatment by the Bessemer process; their only stock was the carbonated iron of Eisenerz, at the extremity of Styria. Therefore, seeing great usefulness in the Thomas-Gilchrist process, these works were the first on the continent to put it in practise.

The bricks employed for the lining had the following composition:

Lime and magnesia,	96
Alumina and oxide of iron,	2
Silica,	2

The most interesting features connected with the experiments at Witkowitz, are the employment of two converters, one with an ordinary silicious lining, the other with a basic lining, and the changing of the metal from one to the other during the operation.

A ladle received from the blast furnace the metal which had the following composition:

Carbon,	5·5—4
Silicon,	2·5
Phosphorus,	0·17

This metal is very low in phosphorus and ought to give no trouble in the special treatment to which it was subjected. By leaving very little carbon and finishing with ferro-manganese they were able to make good rails from it.

The metal after treatment in the first or silicious converter, had the following composition:

Carbon,	0·22
Silicon,	0·81
Phosphorus,	0·20

This metal was cooled in a ladle, which was then lifted by means of a locomotive to the level of the basic converter, in which the refining was finished.

The steel obtained had the following composition:

Carbon,	0·14
Silicon,	traces.
Phosphorus,	0·036

They have not given sufficient details in regard to this operation; for instance, we do not know if there was any overblowing for such a small amount of phosphorus.

The loss was 18 per cent.; as to the product, it was of excellent quality, comparable to that obtained from the best charcoal iron of Austria.

Tests for tensile strength, with bar 100 millimetres in length, gave the following results:

Resistance,	45 kil.
Elongation, per cent.	29 "
Contraction, per cent.	62 "

But what seems to result from changing from one converter to another, at least so far as it has been tried, is that it prolongs the operation 15 minutes and causes a very marked cooling.

Dephosphorization on furnace bed (sur sole) is far from having attained such practical results as dephosphorization in the Bessemer converter.

The question of the production of dephosphorized steel on a furnace bed occupies the attention of many metallurgists; but since my communication of July last, there has appeared no further information with regard to experiments with the Ponsard furnace-converter in Belgium. It will be remembered that in experiments with this furnace, the heat was insufficient and did not permit the entire charge leaving the furnace. The value of the metal in rolling cannot therefore be definitely stated.

The following complete analyses, made in the laboratory at Creuzot, of samples of the metal and of the slag taken during the operation give us all the information we have:

Description.	Rail Metal. Creuzot.	1st Sample.	2d Sample.	3d Sample.	4th Sample.	5th Sample.	6th Sample.	7th Sample.	8th Sample.
Time of Taking Sample.	E.	2 hours.	3h. 02.	3h. 51.	4h. 45.	5h. 45.	7 hours.	7h. 25.	9h. 30.
Carbon total	1·947	1·754	1·572	0·497	0·517	0·150	0·290	0·180	0·405
Silicon	0·454	0·151	traces.	—	—	—	—	—	—
Manganese	0·324	0·180	0·170	0·160	0·125	0·075	0·080	0·075	0·225
Phosphorus	1·611	1·556	1·380	1·104	1·104	0·590	0·359	0·135	0·033
Sulphur	0·322	0·356	0·279	0·240	0·232	0·285	0·255	0·277	0·267
Silica		33·525	21·375	23·500	20·315		17·450	14·786	12·295
Alumina		7·370	5·984	7·786	6·372		11·628	8·468	11·328
Protoxide of Iron		9·102	10·629	10·215	6·570		14·994	27·198	21·987
Lime		19·850	35·700	35·750	40·200		37·100	33·250	32·850
Magnesia		8·784	7·503	8·454	10·394		7·323	6·405	6·917
Phosphoric Acid		1·226	5·556	5·494	4·228		4·962	6·502	2·342
Sulphuric Acid		1·567	0·812	0·687	0·750		0·260	0·572	1·075
Protoxide of Manganese		17·484	11·070	7·905	9·672		4·500	2·371	11·160
Total		98·908	98·629	98·791	98·501		88·217	99·552	99·894
		150 kil. Lime, 118 kil.		Blowing.	Cooling of the Slag: 50 kil. Lime, 137 kil.	50 kil. Lime, 50 kil.	125 kil. Lime, 125 kil.	25 kil. Lime, 25 kil.	Cooled: 60 kil. Ferro-Manganese, 70 per cent.

It can easily be seen, that if the heat had been sufficient they would have been able, with iron containing about 2 per cent. of phosphorus, to have obtained steel containing less than a half-thousandth.

Dephosphorization by the Krupp process.—The Krupp or Narjes-Bender process does not pretend, under the most favorable conditions, to remove from the metal more than 80 per cent. of its phorphorus. This dephosphorization accompanies the almost complete disappearance of the silicon; the product resulting from it, although still containing all its carbon, cannot be used in the Bessemer process. On the other hand, with a highly phosphoric metal, such as that of Cleveland, of the Moselle, or of Luxembourg, which contains 1·5 to 2·0 per cent. of phosphorus, a purified metal is obtained, having still at least 0·3 to 0·5 per cent. of this impurity, which is rather much for employment in the Martins-Siemens furnace. It is necessary to drown this phosphoric material in a mixture of scrap of the first quality, which is another difficulty. The veritable employment of the Krupp process, outside of particular cases, is then the production of non-silicous and notably dephosphorized metal by an operation which seems quite economical; we ought to be grateful for this much. The same pig-iron, easy and advantageous to puddle, would permit the production of improved iron; employed directly in the foundry it would give castings of very much greater resistance. It seems to us, that it is necessary to consider the Krupp process in the above general manner. The results of this process, without doubt very interesting, cannot compete with the Thomas-Gilchrist process, for the production of steel from very phosphoric pig-iron.

In order to complete the data which I have already given, I will make some quotations from the study which Mr. Holley has published in regard to this process.

The furnace is a sort of Pernot furnace for the fusion of steel; that is to say, it is heated by the Siemen's system, and its bed is movable; it has an outside diameter of 4 metres with a "trough" 1 metre in depth. The lining, which has a thickness of 20 to 30 centimetres, is composed of blocks of iron ore, the interstices being filled up with small ore. The surface is glazed by a preliminary heating while the furnace is turned with a speed of only 3 or 4 revolutions per minute. Repairs are made in the same manner by means of a mortar of this same ore, which is applied to the corroded spots.

It is easy to obtain ore of the necessary composition. It must not

contain less than 6 per cent. of silica, in order that it will be able to agglomerate, and not more than 15 per cent. to prevent melting. As to other elements they are not questioned; we thus have dephosphorization with ores having 4 per cent. of phosphoric acid. This is a fact which Mr. Bell had already brought to light in dephosphorizing Cleveland iron with phosphoric ores.

We give below several examples of treatment:

Phœnix Iron.

Description.	Before.	After 4 min.	After 5.30.	After 7.
Carbon,	3·	3·27	3·27	3·32
Silicon,	0·39	0·02	0·01	0·083
Phosphorus,	0·74	0·16	0·146	0·106
Sulphur,	0·09	0·024	0·026	0.029
Manganese,	2·32	0·038	0·116	0·058

Slag.

Silica,	13·0
Oxide of iron,	51.0
Oxide of Manganese,	16·6
Alumina,	11·6
Lime,	0·7
Phosphoric acid	6·0
Sulphuric acid,	0·2

Ilsede Iron.

Description.	Before.	After Treatment.
Carbon,	2·50	2·40
Silicon,	0·20 to 0·30	traces.
Phosphorus,	2·60	0·65 and 0·90
Manganese,	2·60	traces.

Description.	Ore of Ilsede.	Slag Produced.
Silica,	4·80	10·40
Oxide of Iron,	52·60	41·00
Oxide of Manganese,	8·36	19·30
Alumina,	1·20	2·00
Lime,	11·73	7·30
Magnesia,	0·80	0·70
Phosphoric Acid,	3·83	20·00
Carbonic Acid,	7·90	——
Water,	7·88	——

Luxembourg Iron.

Description.	Before.	After Treatment.
Carbon,	3·40 to 3·10	3·30
Silicon,	0·46 " 0·59	traces.
Phosphorus,	2·23 " 2·09	0·65 to 0.95
Manganese,	0·18 " 0·19	traces.

Description.	Luxembourg Ore.	Slag.
Silica,	7·6	9·5
Oxide of Iron,	65·0	70·3
Oxide of Manganese,	0·2	2·1
Alumina,	3·0	4·1
Lime,	10·2	1·9
Magnesia,	2·7	0·3
Phosphoric Acid,	2·2	11·5
Sulphur,	0·1	0·3
Water,	9·0	——

The iron treated ought not to contain more than 1 per cent. of silicon; otherwise the furnace bed would be very much corroded. The less there is of silicon the better the operation proceeds; they sometimes change the composition of the linings by adding a little lime in proportion to the amount of silicon in the pig-metal. Manganese is recommended as facilitating the operation; they add this in the form of spiegel when there is none of it in the pig-metal. Manganese protects the carbon from oxidation, maintains fluidity and produces very good effects.

The charge is from 5 to 7 tons of metal. As soon as it is introduced the rapidity of turning the furnace is increased to 11 revolutions per minute. After two or three minutes boiling, accompanied by disengagement of carbonic oxide, commences. Altogether, the operation is very short, ten minutes at most; as much more time is necessary for stopping the furnace, cooling, etc. One hour and a half is sufficient for the dephosphorization of 5 to 7 tons of metal, repairing and reheating a new lining. Thus 12 hours permits 9 operations, or 80 to 90 tons of dephosphorized metal in 24 hours. The loss is small, and varies from 2·5 to 10·0 per cent. at the most, because there is a slight reduction of the ore used in lining; the operation is, therefore, not very expensive. Mr. Holley published the following information, which is rather insufficient:

1025 kilogrammes of metal, at 58 francs,	60.00 f.
Fusion in the cupola,	4.25 f.
Dephosphorization, lining, coal and labor,	6.25 f.
	70.50 f.

Mr. Peterson, engineer at Eschweiler, gives the following:

Consumption of ore from 18 to 30 per cent., proportional to the amount of phosphorus, without taking into account 6 per cent. of rich oxide of iron in the initial lining, but which is not renewed until the bed of the furnace is completely rebuilt:

Coal,	9 per cent.
Labor,	1.10 f. (about).
Repairs,	0.45 f.

Even taking into account the low price of labor and raw materials in Westphalia, the Krupp process must be considered as not at all costly in any part.

Laws regulating the Spheroidal State of Matter.—P. H. Boutigny states that the temperature of bodies in the spheroidal condition is always below that of ebullition; for water it is 97° (206·6°F.). The spheroidal matter is never in thermal equilibrium with the vessel which contains it, but the vapor which escapes from it is always of the same temperature as the vessel. The spheroidal matter reflects radiant heat. The volumes of matter in a spheroidal condition are in a ratio inverse to their densities, and their masses are uniform. Some of the phenomena seem to indicate a repulsive force acting at sensible distances before vapor can be disengaged.—*Comptes Rendus.* C.

Variations of Temperature at Different Altitudes.—During periods of severe cold in 1879 and 1880 observations at various stations by Alluard, Faye and Lemoine showed that in the basin of the Seine, in the environs of the Puy de Dome, and in various parts of Burgundy, the cold was less intense at elevated stations than at ordinary altitudes. This difference was shown not only in the coldest but also in the warmest parts of the day. At La Croisette, near the summit of the Morvan, one of the most elevated stations, the sky was entirely clear from the 18th to the 28th of December, both by day and by night, while upon the plain there was continual mist and frost. —*Comptes Rendus.* C.

THE RUSSIAN IMPERIAL YACHT "LIVADIA."

The Fairfield Yacht for the Czar, and Vessels of her Type considered as a means of International Communication.*

By E. E. GOULAEFF, Captain of the Corps of Naval Architects, Russian Imperial Navy, Ad.C., F.R.S.N.A., M.I.N.A.

GENTLEMEN: In a few days you will see one of the most remarkable pieces of naval architecture glide gently into the waters of the Clyde. Already hundreds of people have visited the Fairfield Yard, coming nearly from all parts of the globe to see this wonderful ship, intended to serve as the sea-going yacht for the Emperor of Russia, and the interest in her seems to be growing with the growth of the ship.

So novel is this vessel, both in her principal features and in all her details, that her construction shows a wonderful combination of ideas and foresight, proving the extraordinary amount of inventive genius in the mind of her designer.

Being asked by your chairman to read a paper at this Institution, I could not refuse this offer, as I considered it a great pleasure and honor to be able to speak before the Fairfield Association of the "Fairfield child." But, in doing so, I must apologize at starting for my bad English, trusting you will excuse me, as my poor knowledge of your language comes only through my not being a Scotchman.

It seemed to me more suitable, on this occasion, to describe to you the ship herself in as few words as possible, giving only her principal features, and the main objects which were in view in designing her, and to dwell largely upon the probable development of this class of ships, when adapted for great peaceful and beneficial purposes.

The general appearance of the vessel can be judged from the photographs of the model, and from another picture, lying on the table, representing the yacht, when completed, steaming in the smooth sea.

This vessel is 235 feet long, 153 feet broad, and has a draught of 6 feet 6 inches. She might have been a little longer, but on closer investigation it was found that the addition of some 25 feet or 50 feet

* Paper read before the Fairfield Association of Engineers and Shipbuilders.

to her length would not have reduced the resistance in water. Augmentation of skin friction, not being sufficiently compensated by the improved lines, would have required increased power to drive the larger vessel with the given speed. She might have been a little narrower to suit the taste of most people, yet the beam of 153 feet cannot be regarded as being too great if we bear in mind the main object of her design, namely, the desire to secure the greatest steadiness.

Her small draught is perhaps the most peculiar of her features. Experimental analyses, agreeing with actual results derived from the trial trips of extremely broad vessels existing in the Black Sea, prove that at certain speeds a very much broader vessel requires only half as much power compared with another vessel of similar form whose draught is double. This is represented on one of the diagrams. The upper curve shows the resistance of the circular vessel, 120 feet long, 120 feet broad, and drawing 13 feet of the same displacement as the yacht, whilst the lower curve represents the resistance of the yacht drawing 6 feet 6 inches. Hence the importance for the vessels of that class to have the smallest possible draught, and hence the anticipation that great speeds are not incompatible with this form. The late Mr. W. Froude, who conducted, at the request of Admiral Popoff, some experiments with the models of vessels of his design, was the first to demonstrate by exact data the influence of draught on the reduction of resistance. No doubt, such reduction of the total resistance, with the reduction of draught and the increase of other dimensions, is owing to a great diminution of the wave making; indeed, the diagram proves that the advantage of the shallow ship increases with the increase of speed, and, as you all know, at great speeds, according to Froude, the most important portion of the total resistance is the wave making. Such considerations and reasonings, agreeing, as I have stated, with actual trials of the existing vessels—one broader and shallower than another—determined the small draught which has been given to the yacht.

Thus we see that, under the circumstances, the principal proportions of the yacht could scarcely be altered in any way to the advantage of the ship.

Having specified the extreme dimensions, I will draw your attention now to the form of this vessel.

The form of underwater portion was made a subject of very care-

ful study. Besides the great experience of the designer of the ship, Admiral Popoff—experience which he derived by spending the greater portion of his lifetime, either on the ocean, or in constructing novel ships, and trying them at sea—Dr. Tideman, member of the Academy of Amsterdam, was invited to assist in the determination of questions connected with the resistance of the yacht.

In the case of this shallow draughted vessel, the fine lines must be the vertical sections, whereas the fine lines of the ordinary steamer are the water lines or horizontal sections. Such change has been brought about by passing from long, narrow and deep forms of ordinary vessels to the proportions of short, broad and shallow ones; and, as has been demonstrated by experiments with paraffin models, the sharpening of buttock lines is more essential in this case than sharpening of water lines. In other words, if the motion of an ordinary vessel may be compared with that of a wedge propelled vertically, the motion of the yacht ought to be compared with the same wedge propelled through the water horizontally. On looking at the stern of the actual vessel you will observe that the whole motion of the water between the stern tubes will be affected solely in the direction of the vertical sections, or the buttock lines. The diagrams give the principal sections and plans of the yacht. You will see that a large superstructure has been built upon the main body of the turbot-shape of the dimensions and of the form I have just mentioned. This superstructure is of the shape of an ordinary vessel, and because being of usual form, will no doubt gratify the eye of those who are not sufficiently educated to admire the uncovered sides of the lower turbot portion of the ship, which, however, are the very parts that have the greatest share in limiting the rolling at sea. Waves, from whatever point of the compass, developed either by the motion of the ship at very high speed, or by the capricious will of nature, will ascend up the rounded sloping sides of the vessel, but finding there perfect freedom for their play, will have soon to subside, as the sloping deck is of a shape that does not amit of green seas remaining long upon it, unless in the form of a very thin sheet of water, quickly disappearing altogether. No additional buoyancy, therefore, is created alternatively at either side of the ship, and hence the rolling becomes a motion which, in the big waves, might follow the steepness of the swell, and, in small waves, actually reduces itself to nothing. Very often when on board a circular ironclad steaming in a gale, watching the behavior of the boister-

ous seas about the rounded deck of the vessel, I was lost in admiration of the fruitless attempts made by the picturesque phosphorescent waves —illuminated brightly, on a dark night, from underneath by the deck lights—to produce any influence on the majestic steadiness of the ship. At that time, my deficiency in painting prevented me from the reproduction on canvass of my impressions. Here, before you, gentleman, feeling my deficiency in English, I am again prevented from giving to you a better description of the phenomenon; but to complete what I said regarding the behavior of the seas about these vessels in heavy weather, I believe I cannot do better than to refer some of you, desirous of fuller information on that point, to the splendid articles which appeared in the *Times* newspaper from the pen of the eminent writer Mr. Reed, late Chief Constructor of the Navy, who described several passages made by himself on board of these typical vessels, and whose system of widening and shortening ships had much to do with the origin of the idea of circular vessels in the mind of Admiral Popoff. The parts beyond the superstructure already referred to, represent to you the extent of the palace carried by the yacht.

The turbot-like lower part of the vessel contains machinery, coals, and stores of all kinds. The steel superstructure rising over it contains accommodation for the crew forward, and for the officers aft, whilst the palace beyond it includes only the imperial apartments and the cabins for the suite.

This turbot-like portion of the vessel is built of steel, with a double bottom, whose height is no less than 3 feet 6 inches in the centre. This double bottom is divided into forty water-tight compartments, and extends throughout the flat portion of the bottom. At the sides it is superseded by the cells formed by running two vertical bulkheads right round the ship, and subdividing the distance between them and the outside skin into forty other compartments. These side cells, formed of continuous bulkheads, and covered by the plating of the rounded deck, present a very rigid, contiuous, annular structure, which has its lower points tied together by the radial girders, forming the bracket framing of the bottom, and by the heavy beams of the rounded deck, also radial, at the top. Thus the turbot-like portion of the vessel is made amply strong enough to withstand those forces which might be experienced in the roughest seas, and the local strains, such as those produced by the powerful machinery with which the ship is provided—particular attention being paid to the structure of the stern,

in order to distribute the strains on the brackets supporting the propelling shafts of the side screws.

I need not go into the strength of the superstructure that rises above the turbot portion of the vessel, as it has been mainly designed to form a support for the palace and deck-houses beyond, in order to raise them so much above the level of the sea as to prevent anything but spray reaching those portions which are intended for the use of the imperial party.

The palace, as will be seen from the diagrams, is not so wide as the steel superstructure, so that all around it on the deck a continuous gallery is formed, which is used for stowing anchors, mooring the vessel, hoisting up boats, steam launches, and a small steam yacht, carried an the davits, which are supported by bridges projecting radially outwards from that gallery.

The roof of the palace is carried right over to the same width as the lower superstructure, thus forming an awning over the gallery shading from sun or rain the lower story of the palace, and widening at the same time the promenade above. Inside the lower story forward, and away from the heat and smell of the engines and galleys, are the apartments for the emperor, and aft, those for the suite. Their number is not great, but their size is very much larger when compared with the cabins existing on board of any other ship. Accommodations of exceptional comfort had to be studied in this case. In the inside of the superstructure below here in the palace, the middle portion between the engine and boiler hatches is allotted to a passage across the vessel communicating with either end by means of two longitudinal passages, and also with the deck above. Such principal thoroughfare, by its convenience, marble pavements, electric lighting, etc., reminds one of the lofty staircases and spacious corridors in some palaces on land.

Beyond the promenade on the awning deck rises a reception saloon, whose height is 12 feet, and therefore greater than has been reached on board any other ship. In its forward part will play a fountain, surrounded by a bed of flowers. The whole decorative works of this saloon will remind us of the rooms of Louis XVI, at Fontainebleau, and the designs of this and other apartments were prepared by the well-known Scotch artist, Mr. W. Leiper. The drawing-room will be furnished in the Crimean-Tartar style, whilst other rooms will be of a

University of MICHIGAN

simple kind of modern English, regard being made to obtain the greatest comfort.

Behind the funnels on the same awning deck stands another deck-house, including rooms for the Grand Duke Constantine and the captain of the ship. Just in front of the funnels is the bridge, from which the ship will be governed, either by the steam steering gear acting upon her rudder, or by means of another gear designed for steering the vessel by means of her side screws.

It is scarcely possible to enumerate the improvements introduced in all their details. The system of distinguishing red, white and green electric lights has been worked out under the guidance of His Imperial Highness the Grand Duke Constantine. The system of pumping out the water-tight compartments is deserving of special notice, as does also the town-like system of water-service, to which, I believe, for the first time on board ship, there are added loaded accumulators to produce pressure when the steam pumps are not at work. Machinery has been employed largely to supersede manual labor, and there are no fewer than twenty-three separate steam engines on board for different purposes.

The propelling engines of the yacht, which have been designed by Mr. A. D. Bryce, are of a construction decidedly novel, and have been erected in a somewhat novel manner. Their foundation, which is of steel, forms part of the framing of the double-bottom, as is also the case, on a smaller scale, in the circular vessels. We hope that, with many other important improvements introduced in these engines, we shall obtain a greater amount of indicated horse-power, as compared with their weight, than with any other marine engine yet constructed (torpedo boats excepted), and that they will satisfactorily answer the problem entrusted by Admiral Popoff to Mr. Bryce.

The arrangement of propellers forms another very important peculiarity in the design of this vessel.

The efficiency of submerged screws beneath the ship's bottom has been sufficiently tested previously by Admiral Popoff, but so much as having two-thirds of their diameter entirely below the outline of the vessel is a decided novelty, which, as was expected, will greatly add to their efficiency, as has been corroborated by the recent experiments conducted to that effect, on Loch Lomond, with a steel model of the yacht one-tenth the ship's size. There are three screw propellers of 16 feet in diameter, spaced 18 feet 3 inches apart—the centre one being

in the line of keel, and each of them worked by an independent engine capable of exerting an indicated horse-power of 3500.

Now, having described to you the vessel, I shall beg you to turn your attention to the second portion of the paper, namely, to "vessels of her type considered as means of international communication."

During the last few years the means for such communication have reached a high state of development, and the great improvements introduced are already increasing and facilitating commercial, scientific, and friendly intercourse among the nations, and are tending to bring more and more the light of civilization to bear upon those portions of the human race whose isolation from other parts of the world was the only cause of their primitive state.

Already one immense line of railways crossing the continent of Europe, or that of United States of America, from end to end, competes with another line of similar extent, in affording comfort to passengers and in saving so many hours in the journey. Every year the number of railway companies continuing to disregard the comfort of travelers is decreased, and with the sleeping and dining cars introduced on nearly all lines of importance, traveling is done with such ease that the journey becomes no longer a source of trouble but the reverse.

However important in relation to the economical development of separate states are the means of communication just spoken of, there are others which are scarcely of lesser importance, especially so in relation to commerce and civilization—and one of these is the steam navigation. I specified it the steam navigation, because only the application of steam insured the possibility of establishing an uninterrupted connection of all parts of the world. So great is the demand for the means of emigration from the Old World to the New, often in very large masses of people, and the demand for the means of traveling, that already, at least one steamer a day is despatched from the shores of Europe to America, and, no doubt, the same will be the case with our communications with the other parts of the world, such as Australia, as soon as greater knowledge has been obtained of the climate and natural wealth of this new continent. Thanks to the continuous success in ship building—success for which we are greatly indebted to the Clyde shipbuilders—already the distance to America has been decreased to a week's journey, and to Australia, to a passage of one month. I know that Mr. Pearce is not satisfied with these results, though they were brought about partly through his own enterprise,

and is prepared to surpass them, being ready to construct a fleet of steamers that will run the distance from Liverpool to New York in less than six days, and will establish the "Express" Ocean Service.

Thus we see that the great strides in steam navigation have given us nearly as good means of rapid locomotion at sea as have been reached by railways on land, but so much cannot be said in relation to comfort. Notwithstanding an ardent desire on the part of shipowners to turn their steamers into floating hotels, as convenient for living and as luxurious in their internal arrangements as are hotels on shore, people, with very few exceptions, regard a voyage by sea with mistrust, and even with dread, at the thought of that helplessness to which are subjected both men and women, when the calm of the sea, so pleasant to travelers, changes into a heavy boisterous swell whose end no one can predict. No care in improving the internal accommodation, however luxurious—and, in most cases, more luxurious than the interior of the first-class railway carriage, at whatever expense to the owner of the ship the luxury is obtained—can alleviate these feelings of the masses of passengers. Fears of sea-sickness limit at present the number of travelers by sea actually to those who are obliged by necessity to go on board of a steamer of our day. Had the means existed to obviate, or at least to decrease, these inconveniences—nay, sufferings—I can predict that the numbers of those traveling on board the steamers would be increased to an enormous figure, which would result in the construction of new vessels of still greater speed, and with still better accommodation. The intercourse between nations would become much wider, and the beneficent results of enlightenment and Christianity would spread to the most distant countries. The islands forming Great Britain, remain comparatively speaking, in a certain sort of isolation in relation to the people's customs and habits, which make the Englishman abroad so different from any permanent resident on the Continent. The cause of this, according to the opinion of an eminent politician of the present day, can be traced in small and very inconvenient means of Channel communication. If a distance of twenty miles by sea can produce so marked a difference in the people, it seems to me that what I said before in reference to the improvement of the means of communication between one part of the world and another must present itself to our minds still more clearly, and prove that ameliorations in this respect are to be regarded as matters of great importance in the history of the world.

So far, the attempts in the direction of improving the Channel communication—attempts which were met by every one of us with sympathies and hopes, which brought forth the design of such original vessels as the *Bessemer* and *Calais-Douvres*—have failed, and thus the field for improvements in that line remains yet open.

I say that the problem of combining comfort with sea voyages is yet to be solved, not because we are wanting in the knowledge of the principles, the application of which would reduce suffering from seasickness to a minimum, but because, until the present time, there has been no opportunity for constructing a steamer on those principles specially intended for the combination of speed with extreme steadiness in a seaway.

The circular ironclads forming part of the Black Sea fleet were intended for purposes of coast defence, which confined them to a small speed of locomotion so as to be able to use the greater part of their displacement for the purpose of carrying their enormous guns and and armor, which they do actually carry upon their extremely small hull. Quite indirectly, after the completion of those vessels and at the time of their extensive trials at sea, their wonderful steadiness in the heaviest seas was demonstrated, owing to their beam, absence of freeboard and rounded-up deck. Thanks to the voyage of the High Admiral of the Russian Navy, the Grand Duke Constantine, across the Black Sea to Batoum and back along the Caucasian shore, exactly a year ago, many of the distinguished gentlemen who had the honor of attending His Imperial Highness on that occasion had the opportunity to witness for themselves the splendid behavior of these extremely broad vessels at sea, and they ceased to believe any longer in those curious articles in some newspapers which were sufficient only to prove how very little the writers were acquainted with naval architecture and seamanship. During that voyage, the steamer *Penderaclia*, of ordinary proportions, had the full angle of rolling (on both sides) 72 deg., whilst the full arc through which the circular vessel rolled did not exceed 6 deg., or 12 times less. The *Penderaclia's* oscillations per minute were 20 against only 9 oscillations in the same space of time of the circular vessel. These eloquent figures speak for themselves. They were obtained by careful observations made simultaneously on board of each of these two vessels, which were specially placed in exactly the same conditions in reference to the waves and the wind.

Two years ago the imperial yacht *Livadia* was wrecked. There was,

therefore, a necessity for building another vessel to fulfill the purposes of a sea-going yacht. On this occasion H. M. the Emperor, on the recommendation of the Grand Duke Constantine, accepted the design of a new yacht prepared by Admiral Popoff. In recommending these plans H.I.H. desired to demonstrate by this vessel the capabilities and qualities of the very broad and shallow ships, when the strictly defined problem of carrying heavy pieces of artillery and thick armor on a steady platform, capable of moving with moderate speed, is changed into a wider problem—to attain the greatest steadiness on the sea-way with great speed, not less than that of the yacht which was wrecked. Therefore the problem which was to be fulfilled in the new vessel is exactly the same as that upon the successful solution of which depends the wider range of the development of the means of international communication of the whole world.

In less than one year Mr. Pearce, the head of the most eminent shipbuilding and engineering firm in Scotland, and, as you all know, one of the most enterprising men of the day, after having gone through all the calculations of the vessel, and having satisfied himself as to the principles embodied in her design, has built the new yacht, and now she is so far advanced, that she will be launched next week. Carrying the palace high above the sea admits of having such an amount of light and air in it as could not be attained in sea-going steamers of ordinary form; such a palace built on the ordinary form of vessel would, in a too dangerous degree, have reduced the stability. Three sides and the double bottom will prevent the ship from sinking should she be seriously damaged by collision or stranding. Three sides with a distance between them of not less than 6 feet, and extending all around the ship, are incompatible with the narrowness of the present ordinary vessels. Three independent engines will insure the possibility of navigating the ship to the place of her destination with one or even two engines broken down—an advantage of which not one of the existing steamers can boast. After losing the rudder, the yacht is not left helpless—she can be handled as well by steering her by the side screws.

All investigations and experiments with models of the yacht tended to assure us as to the certainty of anticipated results in regard to the speed of this vessel; whilst the passage through the Bay of Biscay in the equinoctial autumn weather is awaited with greatest interest, not only by us, but by all who are watching the progress of the develop-

ment of steam navigation, as on this voyage the yacht will be the very first vessel of such unusual proportions that will have been brought to face the waves of the Atlantic.

It is true, the *Livadia*—which is the name of the yacht I am speaking of—cannot be considered strictly as being intended for oceanic navigation. Her length as well as breadth is too small for such service, the dimensions of the *Livadia* being determined by the desire to build the cheapest vessel of her kind.

Those acquainted with the question—How much the power of machinery is affected by the size of the vessel which has to be driven will easily understand, that it is impossible to compare the *Arizona* or the *Orient*, whose displacement is eight or nine thousand tons, with the yacht *Livadia*, whose displacement is not greater than four thousand tons. It is impossible, by taking such unequal representatives of two so different species, to compare their efficiency in regard to fuel consumed for a run of a certain distance. A smaller ship, of whatform we take, will always have a disadvantage in point of economy; and this very reason makes the shipowners in advance of other persons to order already steamers like the *Servia* and *City of Rome*. When the same dimensions as those of these last two vessels shall be reached in ships having the form of the *Livadia*, and intended for trans-oceanic service, then the consumption of coal necessary to drive such vessels with the speed of ordinary ones will compare better. However, some exact data in this respect of greatest importance will, no doubt, be obtained from the trials of the yacht. Just on the eve of these trials it would be perhaps premature to speak of, and discuss, the expected performances of the yacht and the vessels of her class more than I have done. In conclusion, I shall refer to the subject of dock accommodation.

Docks capable of lifting vessels of the *Livadia* type for the purpose of painting or repairs, have been already constructed and tested in the Black Sea. The system of single-sided floating docks (known as Messrs. Clark and Stanfield's system), adopted for extremely broad vessels by Admiral Popoff, does not any longer prevent the construction of vessels of any proportions.

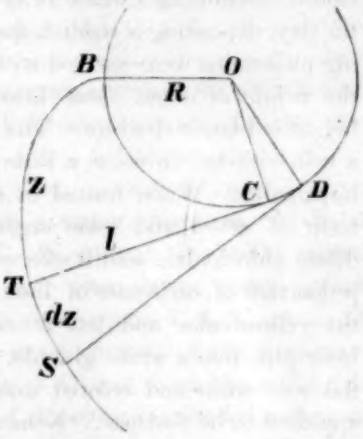
The INVOLUTE of the CIRCUMFERENCE of a CIRCLE.

By J. J. Skinner, Ph.D.

Instructor of Mathematics and Surveying, Sheffield Scientific School, New Haven.

Several years ago I was asked a question like this: Suppose a string 100 feet long to be wound round a vertical cylinder one foot in diameter; if a man takes hold of one end of the string and unwinds it all, by walking around the cylinder, keeping the string stretched, how far will he travel? I solved the general problem as follows:

In the figure let B mark the point where the unwinding begins, and suppose $C\,T$ to represent the part of the string that has been unwound. Denote the length of this by l, denote the radius of the circle by R, and let the *circular measure* of the corresponding angle $B\,O\,C$ be v. Also denote the actual length of the arc $B\,T$ by z. Let $T\,S$ be the differential of z, then the circular measure of the angle $C\,O\,D$ will be dv.



The circular measure of the angle between the tangents $T\,C$ and $S\,D$ is also dv. We shall have

(1) $l = B\,C = R.\,v.$

(2) $d\,z = T\,S = l.\,dv.$ (in the limit.)

By substitution of (1) in (2), $d\,z = R\,v.\,dv.$

By integration,

$$(3) \qquad z = \frac{R\,v^2}{2} = \frac{l^2}{2\,R};$$

which is a general formula, easy to remember, that agrees with formula (2) given by Prof. D'Auria, on page 46 of the July number of the current volume of this Journal.

By making $2R = 1$, and $l = 100$, we find the answer to the question proposed at the beginning of this article to be $\frac{1}{2}10{,}000$ feet.

The area of the figure $B\,T\,C$ is found with equal facility, as follows:

At the limit we have the area included between $T\,S$, and the

lines $T\,C$ and $S\,D$ equal to $\frac{1}{2}\,dz.\,l$, or, denoting the area $B\,T\,C$ by A, we have $d\,A = \frac{1}{2}\,dz.\,l$.

By substituting in this from (2) and (1) we get

$$d\,A = \frac{R^2\,v^2\,dv}{2};$$

By integrating,

$$A = \frac{R^2\,v^3}{6};$$

which agrees with the formula for A given by Prof. D'Auria on p. 47.

Dust Showers.—M. Daubrée has given an account of the dust showers that were observed from the 21st to the 25th of April, 1880, in the departments of the Lower Alps, Isère and Ain. Heavy dark clouds, resembling a dense yellowish mist, traversed the valleys during the day, depositing a reddish dust with a little water. The neighboring mountains were covered with snow, which assumed a rusty hue to the height of about three kilometres (1·864 miles) and above that height it remained white. The snow, upon melting, left a deposit of a yellowish-brown color, a little redder than limonite dust and almost impalpable. When heated in a tube it blackened, with a disengagement of water and some organic matters of a strong odor. With dilute chlorhydric acid it effervesced strongly, showing a considerable proportion of carbonate of lime. Boiling chlorhydric acid destroyed the yellow color and left a residuum which was fusible under the blow-pipe into a white globule. This residuum contained numerous flakes of white and colored mica, together with some particles which appeared to be feldspar. None of the particles were attracted by the magnet, so that the dust was not probably cosmical, but it resembled in its structure the sand of Sahara. F. de Jussieu reports a similar shower at Autun, on the 15th of April, in which there were traces of iron and perhaps also of lead. A shower occurred in Sicily on the 10th of April, which is said to have deposited considerable quantities of metallic iron covered with a thin layer of oxide. Prof. Orazio Silvestri, of the Meteorological Institute in Catania, gives an account of a shower during the night of March 29—30, in which the dust contained particles of iron, small infusoria and organic molecules. Some of the particles were spherical, as if they had been melted.—*Comptes Rendus, Fortsch. d. Zeit.* C.

THE SUMMATION OF SERIES WITHOUT THE CALCULUS.

D'AURIA'S PAPER ON THE "INVOLUTE OF A CIRCLE." *

In this paper the summation of two series are required and accepted, the methods of effecting which appear to be insufficiently demonstrated; a little observation, however, will enable the student to obtain the summation of either of these series without resorting to the higher analyses.

The summation of the first is very simple; thus, writing the series:

$$1 + 2 + 3 + \ldots + (n-3) + (n-2) + (n-1) + n$$
$$n + (n-1) + (n-2) + (n-3) + \ldots + 3 + 2 + 1$$

the same sum is written a second time in inverse order under the first, and the *two* series added together become

$$n + n + n + n + \ldots + n + n + n + n + n$$

when the two series combined evidently become $(n+1)$ terms, multiplying n (the value of the last term) and a single series $= \frac{(n+1)\,n}{2}$

This summation is so elementary as scarcely to call for a demonstration to any one who would read Prof. D'Auria's article, but the summation of the second series, viz.:

$$(1)^2 + (2)^2 + (3)^2 + (4)^2 + \ldots\ldots\ldots (n-1)^2 + n^2$$

is not so readily effected. In this instance, however, let it be considered that the values $(1)^2$, $(2)^2$, $(3)^2$, $(4)^2$ . . . . be the surface of solid plates, the thickness of each plate being unity. Then each plate becomes a square whose sides equal 1, 2, 3, ... n. Suppose these plates to be piled up in a pyramidal form, the base of which is $(n)^2$, on which is placed $(n-1)^2$ and so on to . . $(3)^2$, $(2)^2$, $(1)^2$,] and it is obvious that the sum of the series is included within the solid contents of a pyramid. Such a pyramid of steps will be inscribed within a pyramid of plane sides whose base equals $(n+1)^2$, and whose height $= n + 1$, when the line of the corner of the upper face of each of the supposed planes will be in the plane of the sides of the pyramids, and the apex of the pyramid will be formed upon the topmost block $[(1)^2]$ as a little pyramid of itself, having unity for the side of its base and unity as its height.

The cubic contents of this pyramid will then, by the well known properties of a pyramidal body $= (n+1)^2 \times \frac{n+1}{3}$ or equal the

* July No. of the JOURNAL OF THE FRANKLIN INSTITUTE.

square of the base multiplied by $\frac{1}{3}$ the height. And the cubic contents of this pyramid exceed that of the sum of the superimposed planes, by the aggregate of the cubic contents of the small pyramids or prisms which lie at the corners or along the sides of the several planes.

Thus there is at the apex, a little pyramid with unity for the side of its base and for its height, which has for cubic contents $= (1)^2 \times \frac{1}{3} = \frac{1}{3}$ cubic, and there is also at each of the four corners of each plane from top to bottom, a little pyramid which has $\frac{1}{2}$ for the side of its base and unity for its height, whose cubic contents for each plane becomes $= 4 \times (\frac{1}{2})^2 \times \frac{1}{3} = \frac{1}{3}$; whence there exists $n + 1$ such solids in excess of the pyramid itself $= \frac{n+1}{3}$

There is also surrounding the four sides of the first plane $= (1)^2$ four triangular prisms each $1 \times \frac{1}{2}$ on their base and 1 high to the apex, the sum of the cubic contents of these four prisms:

$$= 4 \times (1 \times \tfrac{1}{2}) \times \tfrac{1}{2} = 1$$

and surrounding the four sides of the second plane $= (2)^2$ four prisms each $2 \times \frac{1}{2}$ on their face and 1 high to the apex, the sum of the cubic contents of which $= 2 \times (1)^3 = 2$, and finally there is for n planes a number of prisms whose aggregate cubic contents equals

$$1 + 2 + 3 + 4 + 5 \ldots . n.$$

This series is the same as that first considered and its sum $= \frac{(n+1)\,n}{2}$

From all this it is seen that the sum of the series

$$(1)^2 + (2)^2 + (3)^2 + (4) \ldots . (n)^2$$

equals $(n+1)^2 \times \left(\frac{n+1}{3}\right) - \frac{n+1}{3} - \frac{(n+1)\,n}{2}$

$$= \frac{n^3 + 3n^2 + 3n + 1}{3} - \frac{n+1}{3} - \frac{n^2 + n}{2}$$

$$= \frac{2n^3 + 6n^2 + 6n + 2 - 2n - 2 - 3n^2 - 3n}{6}$$

$$= \frac{2n^3 + 3n^2 + n}{6} = \frac{n^3}{3} + \frac{n^2}{2} + \frac{n}{6}$$

which is Prof. D'Auria's accepted value for the sum of this series.

This summation can be demonstrated or obtained from a general equation founded on considerations of the exponential equation, but the process is decidedly one appertaining to higher algebra, while the calculus gives the result very readily, but the above is easily comprehended by any one whose mathematics are in form for practical application.

B.

THE BEAUMONT COMPRESSED AIR ENGINE.

The value of compressed air as a motive power has long been recognized, and many attempts to utilize it in this respect have been made, although hitherto they have not always been attended with practical success. The main difficulty which has stood in the way of inventors and has retarded the progress of the air engine has been that of providing means whereby the full power contained in the air under compression can be utilized economically and at serviceable pressures. Judging from the results of some experimental runs made with an air-driven locomotive which we recently attended, this difficulty would now appear to have been mastered, and highly compressed air to have been rendered practicably available as a source of motive power. This has been effected by Colonel Beaumont, R.E., in an engine which has been lately running in the Royal Arsenal, Woolwich, where its powers have been put to the test of practical work. It is now some four years since Colonel Beaumont first commenced experimenting in this direction, and he has proceeded step by step, improving and perfecting as he went on, until he has at last succeeded in producing the engine in question. The construction of this engine is based upon the principle of utilizing the entire power stored up in compressed air, no matter how high the pressure may be. This is effected by admitting the air into successive cylinders, having different areas, commencing with the smallest, and in making provision by which as the pressure falls in the reservoir the consumption of air can be increased. In other words, the elasticity and the expansive properties of air are taken full advantage of in this engine, just in the same way as the corresponding properties in the vapor of steam are utilized in the compound steam engine—that is, in each case the gases are expanded from the smaller and high-pressure cylinders into the larger and low-pressure cylinders.

In appearance the engine necessarily differs from an ordinary locomotive, the absence of a funnel or other outlet for smoke or steam being the most prominent point of departure. The machine, which is noiseless, more or less resembles a large tank, carried upon wheels, with sundry levers and handles on the top, where the driver is placed. The engine in question, however, is not of the form which is to be

adopted in practice, but is that in which the principle has been finally developed, and is now being demonstrated. The air is first compressed by a stationary engine and machinery into the reservoir of the air engine. In the present instance the compression is effected by the machinery in the Arsenal, by permission of the authorities, who have also consented to Colonel Beaumont carrying out his experiments there, seeing that the principle will find an important application in several directions connected with the government, notably in that of electrically-steered torpedoes. The air is stored in the reservoir under a pressure of 1,000 pounds per square inch, and is delivered thence into the first and smallest cylinder at that pressure. After use there it is expanded into the second and third cylinders in succession, each cylinder having an increased cubical capacity in relation to the one preceding it. From the third cylinder, having there given out its last pound of useful effect, the air is ejected noiselessly into the atmosphere from a small port at the side of the cylinder. The first cylinder being of comparatively small area, difficulty might be experienced in starting the engine on a rising gradient or in the presence of other resistances. To meet this point there is an arrangement for admitting the air at full pressure into the second or intermediate cylinder, so that greater power is thus developed at the first stroke. Another difficulty invariably present when highly compressed air is expanded is the extreme cold produced, which, as is well known, is so great that the moisture in the atmosphere becomes condensed and frozen upon the working parts, thereby contributing to reduce the power and efficiency of the machine, and in time to stop its action. This difficulty is met in Colonel Beaumont's engine by the application of heat, externally, to the compressed air. This is effected by means of a diminutive steam generator which is carried on the framing of the engine. So effectual is this application of a mild heat that the expanded air issues from the exhaust ports quite warm.

With this engine we lately made several runs with very satisfactory results, the machine working smoothly, noiselessly, and at a good speed. A number of runs were effected over a straight length of that part of the Arsenal Railway which runs direct from the proof-butts to the Plumstead entrance of the Arsenal, the length traversed being nearly 700 yards. At starting the gauge showed a pressure of 1,000 pounds per square inch in the air reservoir, and at stopping this had become reduced to 820 pounds, showing that only 180 pounds of pressure had

been consumed in the runs which in the aggregate amounted to a little over three miles. The engine weighs 10½ tons, and a truck containing several passengers which it had hauled weighed about 1½ tons more, making a total of 12 tons. The result of the runs, however, was not considered so good as had been obtained upon previous occasions, as a number of stops were made in order to test the controlling and other qualities of the engine. The engine is arranged so as to be able to make a run of 20 miles with one charge of compressed air. What it really has done, we are informed, has been to haul a gross load of 22 tons for a distance of 11 miles, and the lighter load of 12 tons for over 20 miles, with one charge of air, and which it did under the observation of the Arsenal authorities. From these experiments it was deduced that the engine will take three tons one mile with the expenditure of one cubic foot of compressed air. There can be no doubt that the engine so far has worked most satisfactorily, and there can be as little doubt that the new pattern engine, which we understand will soon be running on the Edinburgh and Portobello tramway, will prove as successful. If cost of production, maintenance and working is found to be low, other things being equal, there is a wide future before this system. Not only will it be applicable for tramway service, in which connection it has been mainly developed by Colonel Beaumont, but it will probably be found capable of working the traffic of our underground railways. This would be a great boon both to the railway passengers and to the company's servants. It will be seen that this system of applying compressed air differs from any that has been hitherto in use, inasmuch as it avoids the loss entailed by the use of a reducing valve and the cooling of the air by expansion. The arrangement appears to enable a much greater amount of power to be realized out of a given quantity of energy stored up than hitherto, and the success of the system, so far, entitles it to the consideration of those who are connected with our tramways and railways.—*London Times.*

Treatment of Frosted Potatoes.—The severe winter in France froze such large quantities of potatoes that some of the chemists were induced to experiment upon them, and they found that if the thawed potatoes were thoroughly washed and then dried slowly, in a current of air with a temperature but slightly above the freezing point, all evidences of the frost would be removed.—*Chron. Indust.* C.

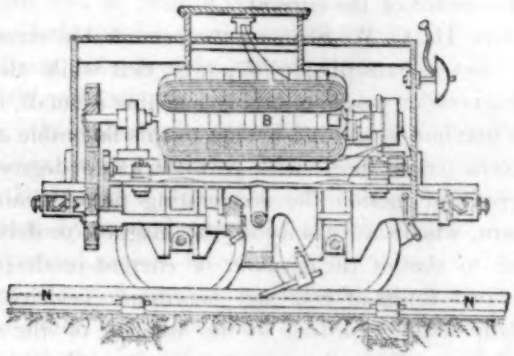
NEW APPLICATIONS OF THE DYNAMO-ELECTRIC CURRENT.

The idea of superseding the steam locomotive by an electric engine is by no means a novel one; but it was never practically realized until last year, when Dr. Werner Siemens built and operated an electric tramway in the grounds of the Industrial Exhibition at Berlin. In connection with the history of this subject it is worth while to mention that an attempt was made to devise an electric locomotive in America some thirty-three years ago. The *Scientific American* for September 25, 1847, contains a description of a new mode of railway propulsion, the joint invention of Mr. Lilly and Dr. Colton of Pittsburgh, Pennsylvania. "The machine," says this account, "is a small locomotive, and is placed upon a circular railway, around which it is driven by electricity. The power is applied not to the locomotive, but to the *track*, in a very curious manner. Two currents of electricity, negative and positive, are applied to the rails, and by them communicated to the engine. The latter is provided with two magnets, which, by a process of alternate attraction and repulsion, drive the car over the track. A piece of lead is placed on the locomotive, making in all a weight of 10 pounds, and on the application of the battery the machine moved with astonishing rapidity up a plane inclined about five degrees." In this apparatus the current was supplied by a battery, a fact which, together with the imperfect state of electric science at the time, doubtless caused its failure.

Another claimant for priority of invention of the electric railway is M. Boué, *sous-intendant militaire* at Belfort, in France. This gentleman took out a French patent in 1878 for the propulsion of carriages on a railway by means of electricity; and not only does the patent describe a means for driving a single train of cars, but also a vibratory apparatus whereby the power of the current may be distributed to several separate trains so as to propel them all. Perhaps, too, we ought to mention that Mr. Edison has of late been relieving his severer labors by the erection of an electric railway, on which it is his delight to whisk his admiring visitors along. Curiously enough he also intends to build a line at a very steep gradient (1 in 6) in order to show the capabilities of his electric railway for overcoming inclines. We say

curiously enough, because that is one of the purposes which Dr. Werner Siemens has expressly stated that the new electric train would be adapted to.

Historical mention is justly accorded to the pioneers of a new invention, though the chief merit rests with him who makes it a success. To Dr. Werner Siemens belongs the honor of recognizing that the improved means now at our disposal for generating electricity and applying it to the transmission of power are sufficient to operate an electric railway on a practical scale.



The Berlin railway was a narrow gauge line, laid down in a circle 900 yards long. A train of three or four carriages was placed upon it, and on the first carriage a medium-sized dynamo-electric machine was fixed to the axle of one pair of wheels in such a manner as to rotate the wheels when the armature of the machine was rotated by the passage of a current through its coils. The rails were laid upon wooden sleepers which even in wet weather insulated the rails very well for this length of line. A third rail between the other two, and it was by this central conductor that the current was led from the generating machine placed at one terminus of the line. The current was drawn from this rail to the armature of the machine on the locomotive by means of a brush of copper wires; and after traversing the coils of the armature it was led to the axle of the driving wheels, which was insulated from the body of the car, and thence by the driving wheels to the outer rails, and by them back to the dynamo machine at the terminus. The annexed figure represents a section through the locomotive, showing the dynamo-electric machine B and the central rail N with the metal brush for abducting the current.

Between twenty and thirty persons could be accommodated on the train at a time, including the conductor, who rode on the first carriage; and during the course of the summer no fewer than 100,000 were conveyed over the line at a speed of from 15 to 20 miles an hour. Crowded trains left the stations every five or ten minutes, and a considerable sum was earned in this way for the benefit of charitable institutions. The locomotive was capable of exerting five horse power, and instead of being fitted with a steam valve like a locomotive to start or stop it, it was simply provided with a commutator for closing or opening the circuit of the current.

"It is," says Dr. C. W. Siemens, "a remarkable circumstance in favor of the electric transmission of power, that while the motion of the electro-magnetic or power-receiving machine is small, its potential force is at its maximum, and it is owing to this favorable circumstance that the electric train starts with a remarkable degree of energy. With the increase of motion the accelerating power diminishes until it comes to zero, when the velocity of the magneto or driven machine becomes equal to that of the dynamo or current-producing machine. Between the two limits of rest and maximum velocity the driving power regulates itself according to the velocity of the train; thus, on an ascending gradient the speed of the train diminishes, but the same effect is automatically produced which results from the turning on of more steam in the case of the locomotive engine. When running on the level, the velocity of the train should be such that the magneto-electric machine should make one-half to two-thirds of the number of revolutions per minute of the dynamo-electric machine. When descending, the speed of the magneto-electric machine will be increased in consequence of the increased velocity of the train, until it exceeds that of the dynamo-electric machine, from which moment the functions of the two machines will be reversed; the machine on the train will become a current generator, and pay back as it were its spare power into store, performing at the same time the useful action of a brake in checking further increase in the velocity of the train. If two trains be placed upon the same pair of rails, the one moving upon an ascending portion, the other upon a descending portion of the same, power will be transmitted through the rails from the latter to the former, and they may, therefore, be considered as connected by means of an invisible rope."

With regard to the relations of work done to energy expended on

the electric railway, the proportion of power actually transmitted varies with the speed of the train, and reaches a maximum when the angular velocity of the armature of the machine on the train is about two-thirds that of the armature of the current generator. Under this condition it is found in practice that something over 50 per cent. of the motive power of the stationary engine driving the generator is utilized in drawing the train.

It is not to be expected that the electric locomotive will compete with the steam locomotive on long lines of railway, any more than the electric light will at present rival gas for general use, but it may prove very serviceable under special circumstances, and on short lines. For steep gradients, tramways in mines, docks, large works, or cities, it is particularly well adapted, owing to its freedom from noise or noxious fumes. It is also well adapted for the transmission of letters along subterranean tubes; and we understand that experiments are being made in Paris with a view to supplanting the pneumatic system of carrying letters by an underground "electric post."

A more important project, however, is the scheme of Dr. Werner Siemens for an elevated tramway to connect one end of the city of Berlin with the other. It is proposed to have two separate lines, one for the going and the other for the return journey. The rails are to be 3 feet 3 inches apart, and only two rails will be required for each line, the current coming from the terminal engine by one line, and returning by the other. Each train has fourteen narrow cars, four to convey standing passengers, and ten for sitting passengers. A 60-horse power engine will be stationed at one end of each line, and the speed will be 20 miles per hour. A good deal of opposition to the project has been offered by the owners of property along the route under the impression that it will depreciate the value of their houses, and a commission has been appointed to examine these objections.

The freedom of the electro-locomotive from smoke is of great importance in passing through a long adit or tunnel, and it is interesting to learn that the administration of the St. Gothard Tunnel seriously contemplate its application to the conveyance of their trains through that gigantic tunnel. Existing circumstances are in this case favorable to the employment of electric power, for at both ends of the tunnel turbines of enormous aggregate power were established to assist in boring, and still stand ready for use. All that has to be done, therefore, is to insulate the rails, and connect up dynamo-electric

machines of sufficient power to the turbines and the train. Instead of insulating one of the rails, it might be advisable to convey the current by a conducting rope resting on wooden or glass supports in such a manner that it can be picked up by the train as it passes, and run over one or more contact pulleys connected to the armature of the machine carried by the train, then deposited again on its insulating supports. In this way, no doubt, the insulation of the rails could be avoided, but it remains to be determined by experiment whether the high velocity of the train would not render such a plan impracticable. —*Engineering.*

Electric Synchronism of Motors and Receivers.—M. Deprez was requested, by one of the French railway companies, to transmit to the interior of an experimental car a rotary movement rigorously identical with that of the wheels of a locomotive, which was attached to a train of which the car formed a part. After having constructed the car with great difficulty, by means of ordinary mechanical contrivances, he thought of the following simpler plan, which proved to be entirely effectual. Two commutators are attached to the arbor of the transmitter; each of them reverses the current twice in one revolution of the axle, but the positions of the arbor corresponding to these inversions follow each other at intervals of a quarter of a revolution. The receiver is composed essentially of a permanent magnet or electro-magnet, between the branches of which are placed two straight electro-magnets, susceptible of rotation around an axis which coincides with the axis of the magnet. If currents of equal intensity are passed into each of the electro-magnets, the right angle which they form places itself in such a position of equilibrium that it is bisected by the straight line which joins the poles of the permanent magnet. Moreover, to to each of the combinations of the transmitter there is one and only one corresponding position of equilibrium for the electro-magnets of the receiver. Therefore, if the transmitting arbor is turned the resulting currents will impress upon the receiving arbor a rotary movement, which will have exactly the same velocity and the same direction as that of the transmitter. The conservation of the angular velocity has been rigidly tested for speeds varying from one to 2400 turns per minute.—*Comptes Rendus.* C.

ON A FOURTH STATE OF MATTER.*

By W. Crookes, F.R.S.

As I find that many scientific men are in doubt as to whether matter has been shown to exist in a state beyond that of gas, I will now endeavor to substantiate my position.

I will commence by explaining what seems to me to be the constitution of matter in its three states of solid, liquid and gas.

1. First as to solids: These are composed of discontinuous molecules, separated from each other by a space which is relatively large—possibly enormous—in comparison with the diameter of the central nucleus we call *molecule*. These molecules, themselves built up of *atoms*, are governed by certain forces. Two of these forces I will here refer to—attraction and motion. Attraction when exerted at sensible distances is known as gravitation, but when the distances are molecular it is called *adhesion* and *cohesion*. Attraction appears to be independent of absolute temperature; it increases as the distance between the molecules diminishes; and were there no other counteracting force the result would be a mass of molecules in actual contact, with no molecular movement whatever—a state of things beyond our conception—a state, too, which would probably result in the creation of something that, according to our present views, would not be *matter*.

This force of cohesion is counterbalanced by the movements of individual molecules themselves, movements varying directly with the temperature, increasing and diminishing in amplitude as the temperature rises and falls.

The molecules in solids do not travel from one part to another, but possess adhesion and retain fixity of position about their centres of oscillation. Matter, as we know it, has so high an absolute temperature that the movements of the molecules are large in comparison with their diameter, for the mass must be able to bear a reduction of temperature of nearly 300°C. before the amplitude of the molecular excursions would vanish.

The state of solidity therefore—the state which we are in the habit

* A paper read before the Royal Society, June 10th, 1880.

of considering *par excellence* as that of *matter*—is merely the effect on our senses of the motion of the discrete molecules among themselves.

Solids exist of all consistences, from the hardest metal, the most elastic crystal, down to thinnest jelly. A perfect solid would have no viscosity, *i. e.*, when rendered discontinuous or divided by the forcible passage of a harder solid, it would not close up behind and again become continuous.

In solid bodies the cohesion varies according to some unknown factor, which we call chemical constitution; hence each kind of solid matter requires raising to a different temperature before the oscillating molecules lose their fixed position with reference to one another. At this point, varying in different bodies through a very wide range of temperature, the solid becomes liquid.

2. In liquids the force of cohesion is very much reduced, and the adhesion or the fixity of position of the centres of oscillation is destroyed. When artificially heated, the inter-molecular movements increase in proportion as the temperature rises, until at last cohesion is broken down, and the molecules fly into space with enormous velocities.

Liquids possess the property of viscosity—that is to say, they offer a certain opposition to the passage of solid bodies; at the same time they cannot permanently resist such opposition, however slight, if continuously applied. Liquids vary in consistency from the hard, brittle, apparently solid pitch, to the lightest and most ethereal liquid capable of existing at any particular temperature.

The state of liquidity, therefore, is due to inter-molecular motions of a larger and more tumultuous character than those which characterize the solid state.

3. In gases the molecules fly about in every conceivable direction, with constant collisions and enormous and constantly varying velocities, and their mean free path is sufficiently great to release them from the force of adhesion. Being free to move, the molecules exert pressure in all directions, and were it not for gravitation they would fly off into space. The gaseous state remains so long as the collisions continue to be almost infinite in number, and of inconceivable irregularity. The state of gaseity, therefore, is pre-eminently a state dependent on collisions. A given space contains millions of millions of molecules in rapid movement in all directions, each molecule having millions of encounters in a second. In such a case, the length of the mean free path of the molecules is exceedingly small compared with

the dimensions of the containing vessel, and the properties which constitute the ordinary gaseous state of matter, which depend upon constant collisions, are observed.

What, then, are these molecules? Take a single lone molecule in space. Is it solid, liquid or gas? Solid it cannot be, because the idea of solidity involves certain properties which are absent in the isolated molecule. In fact, an isolated molecule is an inconceivable entity, whether we try, like Newton, to visualize it as a little hard spherical body, or with Boscovich and Faraday, to regard it as a centre of force, or accept Sir William Thomson's vortex atom. But if the individual molecule is not solid, *à fortiori* it cannot be regarded as a liquid or gas, for these states are even more due to inter-molecular collisions than is the solid state. The individual molecules, therefore, must be classed by themselves in a distinct state or category.

The same reasoning applies to two or to any number of continuous molecules, provided their motion is arrested or controlled, so that no collisions occur between them; and even supposing this aggregation of isolated non-colliding molecules to be bodily transferred from one part of space to another, that kind of movement would not thereby cause this molecular collocation to assume the properties of gas; a molecular wind may still be supposed to consist of isolated molecules, in the same way as the discharge from a mitrailleuse consists of isolated bullets.

Matter in the fourth state is the ultimate result of gaseous expansion. By great rarefaction the free path of the molecules is made so long that the hits in a given time may be disregarded in comparison to the misses, in which case the average molecule is allowed to obey its own motion or laws without interference; and if the mean free path is comparable to the dimensions of the containing vessel, the properties which constitute gaseity are reduced to a minimum, and the matter then becomes exalted to an ultra-gaseous state.

But the same condition of things will be produced if by any means we can take a portion of gas, and by some extraneous force infuse order into the apparently disorderly jostling of the molecules in every direction, by coercing them into a methodical rectilinear movement. This I have shown to be the case in the phenomena which cause the movements of the radiometer, and I have rendered such motion visible in my later researches on the negative discharge in vacuum tubes. In one case the heated lampblack and in the other the electrically excited

negative pole supplies the *force majeure* which entirely or partially changes into a rectilinear motion the irregular vibration in all directions; and according to the extent to which this onward movement has replaced the irregular motions which constitute the essence of the gaseous condition, to that extent do I consider that the molecules have assumed the condition of radiant matter.

Between the third and fourth states there is no sharp line of demarcation, any more than there is between the solid and liquid states, or the liquid and gaseous states; they each merge insensibly one into the other. In the fourth state properties of matter which exist even in the third state are shown *directly*, whereas in the state of gas they are only shown *indirectly*, by viscosity and so forth.

The ordinary laws of gases are a simplification of the effects arising from the properties of matter in the fourth state; such a simplification is only permissible when the mean length of path is small compared with the dimensions of the vessel. For simplicity's sake we make abstraction of the individual molecules, and feign to our imagination *continuous* matter of which the fundamental properties—such as pressure varying as the density, and so forth—are ascertained by experiment. A gas is nothing more than an assemblage of molecules contemplated from a simplified point of view. When we deal with phenomena in which we are obliged to contemplate the molecules individually, we must not speak of the assemblage as *gas*.

These considerations lead to another and curious speculation. The molecule—intangible, invisible, and hard to be conceived—is the only true *matter*, and that which we call matter is nothing more than the effect upon our senses of the movements of molecules, or, as John Stuart Mill expresses it, "a permanent possibility of sensation." The space covered by the motion of molecules has no more right to be called matter than the air traversed by a rifle bullet can be called lead. From this point of view, then, matter is but a mode of motion; at the absolute zero of temperature the inter-molecular movement would stop, and although *something* retaining the properties of inertia and weight would remain, *matter*, as we know it, would cease to exist.

Aerial Photographs.—By placing a camera in an aperture in the bottom of the car of a balloon very successful negatives have been recently obtained in Paris of the landscape below.

HOLMAN'S NEW COMPRESSORIUM AND MOIST CHAMBER.

By JOHN A. RYDER,
Of the United States Fishery Commission.

In working with living animal forms suitable for the elucidation of some of the principal doctrines of life, any contrivance which will render the study easier, and hence more profitable and economical of time, should be hailed with delight by the working microscopist. Such a labor-saving device is represented in the accompanying cut, Fig. 1, of Mr. D. S. Holman's new compressor. This apparatus

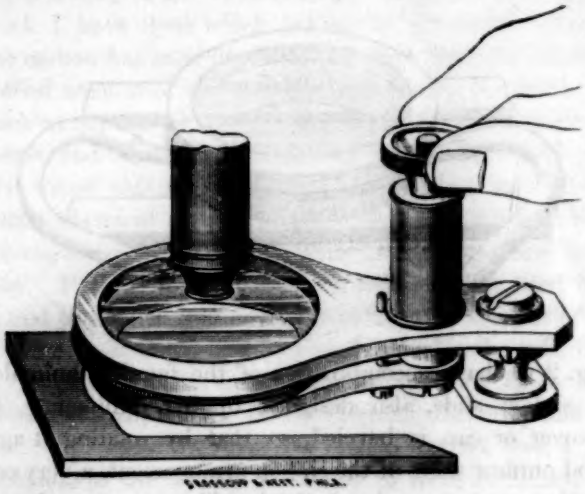


Fig. 1.

differs from all other compressors in being so arranged that the mica cover is fixed and immovable, while the lower, thicker plate of glass is moved up and down by means of a screw nut and spiral spring, an arrangement which enables the student to adjust the apparatus so as to apply *with certainty* any degree of pressure upon any soft object without risk of breaking large and expensive cover glasses, crushing the object unexpectedly, or injuring high-power lenses. The writer by

its means was enabled to study with great deliberation and certainty the internal anatomy of the larva of the plumed crane-fly (*Corethra plumicornis*). In this case the pressure could be so nicely adjusted as not to disturb in the slightest degree the normal physiological actions of the larval fly; the physiological action of the heart could be readily studied, as well as the significance of the so-called apolar ganglion cells of that organ appreciated. Every life process, in short, was visible through the transparent body of the creature, so that if *well* studied by the help of this apparatus, the student will have acquired a mental image or epitome of the morphology and physiology of that great group of jointed animals, the *articulates* of the naturalist.

Equally good results were got by its use in studying the embryology of the shad, where it revealed to the writer, and for the first time to science, the presence of a so-called polar vesicle in the earliest stages of development.

Fig. 2.

In Fig. 2 we have a combination of the familiar animalcule cage and the siphon slide, also designed by Mr. Holman. The edge of the cover or cap is beveled, so that by rotating it against the inflow and outflow tubes of the siphon arrangement, a very convenient and effective compressor is obtained. The apparatus is equally as valuable as the compressor before described, because of the certainty with which one can gauge the amount of pressure which is applied; also on account of the facility with which water may be renewed in it when used as a "moist chamber" for studying growing fungi, without in the slightest degree disturbing these delicate plants. The value of the apparatus is further enhanced by the facility with which it may be used as a siphon slide for keeping aquatic larvæ, worms, etc., alive for a lengthened period for study or exhibition. It is equally useful as a

dry compressor for holding, studying and drawing minute soft-bodied insects in the living state. These useful pieces of apparatus should be found upon the table of every working microscopist, where every day's use will demonstrate their indispensibility. It was in one of Mr. Holman's siphon slides, right under the microscope, that the writer successfully hatched young shad, a feat never before performed with the eggs of fishes.

ON THE ARTIFICIAL FORMATION OF THE DIAMOND.

By J. B. Hannay, F.R.S.E., F.C.S.

Paper communicated to the Royal Society by Prof. G. G. Stokes, LL.D.

In a preliminary notice, which the Royal Society has done me the honor of publishing in the "Proceedings," I gave a very short sketch of the work I have done which led me to a reaction whereby hard crystalline carbon has been produced. I have now the honor of laying a detailed account of the methods and results before the Society. As far back as September, 1879, I was searching for a solvent for the alkali metals, and tried experiments with many liquids and gases, but invariably found that when the solvent reached the permanently gaseous state chemical action ensued. This was the case even with hydrocarbons, the metal combining with the hydrogen and setting free the carbon. Paraffin spirit, boiling at 75°, was first used in experimenting, and the spirit contained a considerable amount of olefines; but even these unsaturated hydrocarbons seemed to be split up in like manner. The experiments were conducted in thick tubes from 1 to 1·5 millims. internal, and 10 to 15 external, diameter, and made of hard glass. In some cases when the carbon was set free, a considerable proportion of the hydrogen seemed to have combined with the higher olefines and paraffins, rendering them gaseous, most of the gas, however, being formed by the reaction discovered by Thorpe and Young, where a high paraffin splits up into lower olefines and paraffins. This reaction, I would remark in passing, is not always the only one to take place, as a mixture of lower paraffins and olefins on being heated under very high pressure sometimes yield a small quantity of a higher or even nearly solid paraffin, as well as gaseous products. An attempt was made to obtain solid paraffin in quantity by this method, but only traces were obtained white enough for use.

The alkali metal which decomposes the hydrocarbon retains a quantity of pure hydrogen, which may be seen by exhausting it by the Sprengel pump. A piece of sodium was exhausted in the molten state for five hours by the Sprengel pump, and when no more hydrogen had been evolved for an hour, a piece was placed in a tube with paraffin spirit and heated for two hours, and when a considerable quantity of carbon was deposited, as much of it was removed as could be conveniently obtained and again exhausted, when 32 times its volume of hydrogen was extracted from it. This was repeated several times, and quantities of hydrogen, varying from 17 to 25 times the volume of the sodium, obtained. The carbon deposited on the tube is of a hard scaly nature, and when the sodium is slowly oxidized and dissolved in water, some very hard scales of carbon are often obtained. This was then the reaction on which my work was built. As potassium is a metal of stronger affinities, I thought that an examination of its action on paraffin would yield somewhat better results, but in this I was disappointed. Sometimes its action was very great, but it seemed to combine with some of the substance in the tube, and formed black compounds, having no hard carbon amongst them. Some of the experiments did yield a little, but on the whole it was not so good as sodium. Lithium was next tried and yielded results which were much more hopeful. When the same paraffin spirit was used the lithium floated on it, but by melting the metal in the bottom of the tube it adhered to the sides, and did not float to the top unless any portion became detached. The appearance shown by lithium is sometimes very beautiful, a small globule of the metal when it has liquefied showing, before it begins to act energetically upon the hydrocarbon, a very beautiful play of colors. After this has gone on for a little a more rapid reaction sets in as the temperature rises, and carbon is deposited somewhat more plentifully. Sometimes a piece of the metal will float until it becomes coated with carbon and it then sinks. The carbon so obtained is harder than when sodium is employed, and will often scratch glass easily. I thought that if I could by increased temperature dissolve the nascent carbon in the metal I might obtain diamond; but after very many trials I did not succeed in doing so. Many of my scientific friends who had witnessed my experiments thought that a gaseous solvent for carbon might be found, and as this was the direction of my general work, I abandoned these metallic experiments and went into a more direct examination of the question

of gaseous solution. As by far the greater number of substances with which we are acquainted are found by the intervention of water and are only soluble in water, I thought that an examination of the solvent effects of water under different circumstances would be likely to yield important results. I found that hard glass tubes resisted the action of water after it had passed its critical point for a time sufficiently long to enable an observer to see whether any great change had taken place in the solution contained in the tube. By these means it was found that many chlorides, sulphates, and nitrates were as soluble in water-gas as in water, if not more so, and that at least no sudden change of solubility was observable at the critical point. By such a process, however, only qualitative results could be obtained, and a series of experiments was tried, using various volumes of water with a fixed proportion of silica in iron tubes, and the solvent power of the water estimated in a more accurate manner. An account of this work will, I hope, be laid before the Society shortly; in fact, as soon as I have the necessary time for completing the work and writing it up. The general result obtained from these experiments was that the solvent power of water was found to be determined by two conditions: 1st. Temperature or molecular *vis viva;* and 2d. Closeness of the molecules on pressure, which seems to give penetrative power. From these observations it will be seen that if a body has any solvent action on another and does not act upon it chemically, such solvent action may be indefinitely increased by indefinitely increasing the temperature and pressure of the solvent. In nature, the temperature has been at one time higher than we can obtain artificially, and the pressure obtained by a depth of 200 miles from the surface is greater than can be supported by any of the materials from which we can form vessels. It will thus be seen that, whereas in nature almost unlimited solvent power could be obtained, we are not as yet able to reproduce these conditions artificially. Could pressure alone increase solvent power then much might be done, but pressure only acts by keeping the molecules close together when they have great *vis viva*, and this latter is only obtained by high temperature.

As glass tubes were quite out of the question when a red heat and very high pressure were required, iron tubes were resorted to, and a series of attempts made to dissolve carbon by various gaseous solvents. The difficulty of closing iron tubes as compared with glass tubes caused me to try various methods, which I shall describe here. Tubes were made

of strong hydraulic tubing, 20″ long, 1″ thick, and ½″ bore. These were fitted with a plug, screwed with a strong screw fitting very well. There was placed in the tube some powdered charcoal from which all the inorganic matter had been removed by immersion in hydrochloric and hydrofluoric acids and washing with water, and then sufficient paraffin spirit to fill the tube two-thirds of its volume. The plug was screwed in with a lute composed of silicate of soda and manganese dioxide, but after heating the tube in a reverberatory furnace for four hours it was found to be impossible to remove the plug, so the end had to be bored out. There was neither liquid nor gas in the tube, the luting having leaked. Another tube similarly filled was fitted with a plug with a copper washer, the end of the tube, plug, and washer being polished, but this also leaked and no result was arrived at. Baryta, clay, asbestos, and other substances, wet with silicate of soda, were all tried with the same result—leakage. A silver washer kept comparatively tight, but only on one occasion. It was thus seen that screw-closing would give no reliable results, so another method was tried. A ball of iron, fitting the tube tightly, was placed in it after the materials had been introduced. The end of the tube was then narrowed by compression between rollers and turned smooth inside. The iron ball was then drawn up by a wire attached and luted by silicate of soda and fine manganese dioxide. It was expected that the pressure would only serve to make the closing more secure, but, on heating, the iron yielded and the ball was driven out with a loud explosion. After trying several other methods of closing—outside screwing and filling the mouth with molten metal on the top of a clay plug being amongst them—I came to the conclusion that nothing would suffice but welding up the open end. This has been, when carried out efficiently, invariably successful, and in all my later experiments I have used it alone. It requires great skill on the part of the workman, and it is only one man in a hundred who can perform the operation with invariable success. The furnace used in these experiments was a reverberatory one, 6 feet long (internal measurement) and 2 feet broad; fire-place, 15 inches; bridge, 9 inches; hearth, 4 feet. The roof sloped down towards the flue and the spent gases had exit at the level of the hearth, thus carrying the flame down as it receded from the fire, in order to have the hearth of one temperature. The walls were 13 inches thick, and the roof formed of 4-inch fire-clay covers.

Three tubes, $20'' \times 1'' \times \frac{1}{2}''$ bore, were filled as follows:

No. I. 3 grms. sodium, $\frac{3}{4}$ full paraffin spirit.
" II. " " $\frac{2}{3}$ " "
" III. " " $\frac{3}{5}$ " "

On heating them in the reverberatory furnace, No. I exploded before a visible red-heat had been obtained, so the temperature was not allowed to rise any higher, and Nos. II and III allowed to lie for four hours and then slowly cooled. On being bored open next day, No. II contained a little scaly carbon, but No. III contained almost none, and nearly all its liquid had been converted into gas, which rushed out on boring it open. It was noticed by the workmen that the inside of the tube was harder to bore than the outside, and I thought, as I found out afterwards rightly, that the iron had been carbonized and converted into steel. It seemed, then, that the free carbon had been taken up by the iron. The same two tubes were welded up again, rather more than half-full of liquid, and slowly heated, but before they came to as high a temperature as they had been subjected to formerly, they exploded together. Two more were filled, welded, and heated, but again they burst simultaneously. It appeared, then, that those tubes were too weak, so two were made $20'' \times 2'' \times \frac{1}{2}''$ bore. On trying to weld them when two-thirds full, the liquid got hot, and gave off enough vapor to carbonize the white-hot plug and made a bad weld, so that they had to be kept cool by trickling water upon them immediately below the hot part. Several tubes were lost in closing before the workman became deft enough at closing them. Two were at length obtained well closed, and were heated, but again, before a red-heat was reached, they exploded simultaneously, smashing the roof of the furnace. It seemed on examining the tubes that one had gone off first, and struck the other such a blow as caused it to burst, as one had a mark near the middle as from a blow with a hammer, and was bent a little. It became plain, then, that two should not be heated together, at least where they might stike each other on explosion. Then, again, as the iron took up the carbon set free, I considered that the reaction might be favored by adding some carbon to the liquid in the form of lamp-black, so that the liquid would be kept always saturated. A tube, $20'' \times 2'' \times \frac{1}{2}''$ bore was filled, as before, to about three-fourths of its volume, and about half a gram of lamp-black added. This was heated to just below a red-heat for six hours and allowed to cool slowly. On being cut open there was a considerable yield of scaly carbon, and

the sodium, on being dissolved, left a few pretty hard scales, along with ferric oxide, spongy iron, etc. This was encouraging, and another tube was filled in the same way, but it burst on heating. An experiment was then tried with paraffin spirit and lamp-black alone, only about 2 grms. of lamp-black being added to the tube, three parts filled with hydrocarbon. This experiment went successfully, and on opening the tube after the outrush of gas it was found that nearly all the lamp-black had been absorbed by the iron. This showed that my conjecture was right about the disappearance of the carbon. Two divisions were then built upon the furnace-hearth, so as to divide it into three spaces, and three tubes of the above dimensions, and filled as follows, were put in them:

No. I. 3 grms. naphtha, ½ grm. lamp-black, ½ full paraffin spirit.
" II. " " " " ⅔ " "
" III. " " " " ¾ " "

On heating, No. II burst with a loud explosion, but did not harm Nos. I and III, but on opening these next day they were found to have leaked, so that there may have been no pressure inside them at the time. Other two, two-thirds filled with liquid and solids as above, also burst; but as I was absent I do not know at what temperature they were.

It seemed plain that the tubes were much too frail, and although they were made from "Lowmoor" iron, well hammered, and the tube bored out of the solid, they invariably burst lengthwise, showing a reedy structure. I determined then to try tubes on the coil principle; so two were constructed out of the toughest bar iron, made solid, and bored out afterwards. The dimensions were $20'' \times 2\frac{3}{4}'' \times \frac{1}{2}''$, and they were heated to a just visible red-heat, and contained 3 grms. sodium, ½ grm. lamp-black, and two-thirds full of paraffin spirit. The heat was kept up eight hours, and the tubes allowed to cool in the furnace. Both kept tight, and yielded some hard scaly carbon, but nothing else. One was tried with lithium, and a better yield of carbon obtained, and it was also harder. Two more tubes of the same dimensions, with lithium, burst, and so were lost. It now became evident that much stronger tubes were necessary for this reaction, or that some other reaction would require to be found.

I would here mention a fact which, although not directly connected with our subject, is of great interest to students of chemical physics. When introducing the alkali metal into the tube it was found necessary

to push it down with a rod, and in one or two cases when I had mislaid the iron rod for the purpose I used a glass rod, of which the end had not been rounded by fusion. In consequence, some small particles of glass became detached, and being lead glass they were heated to such a temperature that they were softened, and in some cases completely melted by the heat. Whenever this had taken place the piece of glass had cavities in it, and these cavities were partially filled with liquid or compressed gas, generally with a portion of each. In the same piece of glass the bubbles were of different size, and often filled to different heights with liquid, just as we find liquid carbonic acid and water filling in different proportions the cavities in the same quartz crystal. How these cavities in the glass are formed, and how the liquid gets into them, I cannot at present determine, but even little spheres of glass purposely introduced likewise developed cavities containing liquid on being fused under pressure. As this is a part of the subject I am investigating, the results being easily produced, I shall reserve its full discussion until I have examined it from various points of view, and varying the substances employed. I think it right to mention it here, however, as I have so little leisure and so many interesting discoveries just touched upon, and each one more tempting as a field of labor than the other, that it may be some time before I can have full data on the subject.

The iron used in making the tubes is what is known as "Lowmoor" iron, a very pure and strong quality, and a portion removed from the interior of a tube which has been used gave, on analysis, 2·17 per cent. of carbon, showing to what an extent carbonization had gone on.

Having obtained results from this process of a kind which showed that diamond was unlikely to be formed by its agency, I reverted to the original idea of solution of carbon in a gaseous menstruum, and from some experiments I had been carrying on with the view of finding some commercial use for "bone oil," I concluded that the distillate from bone oil containing the nitrogenous bases would be most likely to yield such a solvent. Bone oil, the nitrogenous distillate obtained in the manufacture of bone char, and for a plentiful supply of which I am indebted to Messrs. John Poynter and Sons, of Glasgow, was distilled, and the portion boiling between 115° and 150° was taken and rectified over solid caustic potash, and latterly over sodium. When satisfied that it was free from moisture, oxygen, and sulphur, a tube, $2\frac{1}{4}'' \times 20'' \times \frac{1}{2}''$ bore, was three parts filled, and some charcoal powder

added, and the whole welded up solid. I found that the nitrogenous liquid was even worse to work with than the hydrocarbon, as on coming into contact with the hot iron it burnt it away at once, and as the tube was of great diameter it was extremely difficult to keep the lower part cool. For welding it had to be arranged so that it was standing in of tub of ice, and the top projecting through the bottom of the forge, and heated until it was at a welding heat, with as little delay as possible. When a tube was obtained welded up solid it was heated to a dull red-heat for 14 hours, and allowed to cool; on opening the tube there was a very great out-rush of gas, and the carbon was to a certain extent dissolved, and some minute portions of it very hard. Still, under the microscope it presented little difference in appearance from the wood charcoal employed, some of the features, however, being obliterated, and it had a bright appearance. Another tube of the same dimensions and contents was closed up in the same manner, but after eight hours' heating it burst with a loud explosion. I had noticed that a tube which had been once used and been partially carbonized would not stand a second heating, and for this reason I had no belief in the power of cast-iron or steel to withstand the great pressure at a red-heat. Nevertheless, as many of my friends had urged upon me to try these materials, I had a cast-iron tube made, $3\frac{3}{4}'' \times 24'' \times \frac{1}{4}''$ bore, and filled two-thirds of its volume with bone oil distillate and carbon, and then welded up. We succeeded after a little trouble in making a good weld, and the tube was then slowly raised to a dull red-heat in the furnace. It had not been heated for more than an hour when it exploded with a great noise, and knocked down the back and one of the ends of the furnace, leaving the whole structure a wreck. The tube had broken into small fragments, and was quite unlike the malleable iron tubes which generally tore up. Thinking that it was perhaps a bad casting, I tried another, but it leaked all over, and emptied itself before the temperature was nearly up. A third tube of the same material burst like the first, but as I had built up the furnace with large blast-furnace blocks, it was not blown down. Cast-iron being inadmissible, experiments were then made with steel. I had several tubes made of this material by the best firms in the kingdom—made by the three methods, Bessemer, Siemens, and the crucible method—but they had the same faults as cast-iron, although to a less degree. The difficulty in making a good weld in cast-iron and steel tubes makes their employment in such experiments as these a matter of incon-

venience. Out of five tubes made of steel, some of which were made of the very toughest material manufactured by Messrs. Cammell and Co., only one held in the substance completely. Three burst in the furnace, and one had leaked by its porosity. The top of the furnace, by the continued shocks of explosions, fell in at the bursting of the last of the steel tubes. The continued strain on the nerves, watching the temperature of the furnace, and in a state of tension in case of an explosion, induces a nervous state which is extremely weakening, and when the explosion occurs it sometimes shakes one so severely that sickness supervenes.

It appeared that as the bone oil had so hardened the carbon, if it acted upon nascent carbon it might harden it so much as to produce diamond. An experiment was accordingly tried in which bone oil distillate and paraffin spirit were mixed, so that when an alkali metal was made to act upon it the decomposition of the hydrocarbon might yield carbon which would be crystallized by the action of the nitrogenous liquid. The proportions used were 90 per cent. bone oil and 10 per cent. paraffin spirit, with lithium as the metal. The tube used was a coil-tube of Lowmoor iron, 4 inches in external, $\frac{3}{4}$-inch internal diameter, and 24 inches long. Three grms. of lithium was employed, and the tube filled three parts of its length with the mixed liquids, a little lamp-black added, and welded up. It was heated 14 hours to a dull red-heat, and then bored open. A very high pressure was found to exist inside the tube, and as the material was at the other end of the tube it was removed by a long punch. It was found to be a mixture of carbon and lithium compounds, with some cyanides. Some of the carbon was very hard, but could be crushed by agate, and would not scratch it; but there was mixed with it (as with many of the other experiments) a few grains of silica. This was, perhaps, introduced in the welding, as a little silica had to be employed here, and a little may have been added with the lamp-black, which was never quite free from sand or other accidental impurity. The silica particles were easily removed by placing the substance on the stage of the microscope, and examining by polarized light, when all the particles which showed rotary power were removed.

The results obtained by the use of the two liquids being so much more satisfactory, further experiments were undertaken in this direction, and a series of four tubes filled with varying proportions. The

tubes had the dimensions $20'' \times 3\frac{3}{4}'' \times \frac{1}{2}''$ bore, and had 3 grms. of lithium introduced into each and then filled as follows:

No. I.	80 per cent. bone oil,		20 per cent. paraffin spirit			5 grms. of lamp-black added to each.
" II.	40 "	"	60 "	"		
" III.	20 "	"	80 "	"		
" IV.	10 "	"	90 "	"		

These were heated separately in the furnace, with the result that Nos. I and III burst, and Nos. II and IV withstood the pressure. No. II on being bored open gave off a great volume of gas, but on removing the contents nothing but lithium compounds and soft carbon was obtained. No. IV also evolved much gas, but the solid matter was very hard and contained some hard particles of carbon, but no diamond. It seemed therefore probable that some such proportion of ingredients might yield successful results, and another series of five, ranging from 30 per cent. to 10 per cent. of bone oil distillate, was prepared, and not one of them gave any results. One by one the tubes exploded, and the furnace had to be reconstructed at the fourth experiment. I thought I should either have to abandon the attempt or begin experiments of a very expensive nature, using large tubes and a large furnace, as 20-inch tubes of a greater diameter than 4 inches could not be closed when three parts filled—at least by welding. As some of them, however, seemed to stand, I determined to make some further trials with the apparatus I had at my disposal; so another tube, $20'' \times 4'' \times \frac{1}{2}''$ bore was filled, using 4 grms. of lithium and a mixture of bone oil, carefully rectified, 90 per cent., and paraffin spirit 10 per cent., using these proportions because I had never had any results with a high percentage of bone-oil, the tubes so filled having burst. The tube was closed with great difficulty, being three parts full of liquid, and then heated to a visible red-heat for fourteen hours, and allowed to cool slowly. On opening the tube a great volume of gas was given off, and only a little liquid remained. In the end of the tube which had been the upper end in the furnace, the tube lying obliquely, there was a hard smooth mass adhering to the sides of the tube, and entirely covering the bottom. As I had never obtained all the solids in one piece before, I wished to examine it, and so had the other end of the tube cut off, exposing the hard mass. It was quite black, and was removed with a chisel, and as it appeared to be composed principally of iron and lithium it was laid aside for analysis. I was pulverizing it in a mortar, when I felt that some parts of the

material were extremely hard—not resisting a blow, but hard otherwise. On looking closer, I saw that these were mostly transparent pieces imbedded in the hard matrix, and on triturating them I obtained some free from the black matter. They turned out to be crystalline carbon, exactly like diamond. I shall describe further on the analyses, etc., but will here go on with the account of my further experiments. Two tubes were filled in the same manner as the last, but one burst on heating, and the other had leaked so that there was no reaction. Two more tubes were prepared, but were spoiled on welding, and on cutting off the carbonized portion the remainder was too short to work. After much trouble three tubes were obtained, well closed, in which the three alkali metals were inclosed with liquid containing 20 per cent. bone oil and 80 per cent. paraffin. All three stood, and, on opening, only the potassium one had leaked to any extent. The results were not good, however, the sodium tube containing only soft scaly carbon, and the other two very little better. The reaction did not seem to have proceeded in the same manner in the lithium tube as before, as the mass was soft and friable. Still, lithium seemed to yield the best results, so it was adhered to in the further experiments. A list of disasters now awaited me. Eight tubes failed through bursting and leaking, and one of the explosions, when two were being heated together, destroyed a part of the furnace and injured one of my workmen. Besides this, two tubes were spoiled in welding. However, I had four experiments after this, all withstanding the pressure, and in one of these, with 10 per cent. bone oil and 90 per cent. paraffin spirit, a small quantity of diamond was found. The contents of this tube were different from the other successful one, being much looser and not in the same hard mass as the first. In another series of six experiments two were at first thought to have been successful, but I afterwards found that one of them was not so, the transparent matter being siliceous, but insoluble in cold hydrofluoric acid, although it dissolved on boiling. The uncertainty and great expense involved in using these forged coils of iron with tubes bored out of the solid induced me to again try steel, and Messrs. Cammell & Co. having prepared some tubes for me, I tried them, but with the same results—they exploded into fragments at a red-heat. And herein they are much more dangerous than coiled tubes, because the latter seldom fly into fragments, but just tear open a little. A further unforeseen danger in using steel tubes was discovered. One

which had stood the heating very well was being bored, and when the inner skin was cut so that the gas rushed out, the whole exploded, endangering the life of the workman who was boring, but as he was standing at the end of the tube and the pieces flew laterally he was not hurt. I have performed over eighty experiments, and have only obtained three results of a successful nature. The identification of the crystalline pieces as carbon was easy enough, but I have been anxious to find whether they are pure carbon or a compound with some other element, and to that end the following experiments were conducted.

A portion of the substance from the first successful experiment was weighed out after it had been freed from all foreign matter adhering to it, and placed in a very small platinum boat made of a strip of thin foil, the ends of which were wrapped round two stout platinum wires which were sealed into a wide glass tube. The carbon particles were transferred to this boat after being weighed, and the tube connected by india-rubber stoppers with an oxygen gasometer on the one side and a series of potash bulbs on the other. The oxygen was dried over solid caustic potash before entering the tube, and again after leaving the potash bulbs. The carbon (14 mgrms.) having been weighed out, the potash bulbs were weighed, and a current of oxygen passed through the apparatus, and the platinum wires connected with a battery strong enough to heat the foil to a bright red-heat. After a few minutes the oxygen was stopped and the bulbs weighed, when it was found that they had gained 1 mgrm. On repeating this operation no gain was found, the moisture having been entirely driven off by the first treatment. The carbon was now placed in the boat and a slow current of oxygen started, then the bulbs connected and the current made to pass through the platinum until all the diamond had been burnt, when the current was stopped and the oxygen allowed to pass for fifteen minutes more, when the bulbs were detached and weighed. They were then reconnected and the gas passed for another ten minutes to find whether all the carbonic acid had been expelled and reweighed. They weighed 0·2 mgrm. less than before. The numbers were as follows:

Potash bulbs before combustion,	43·8308	
" " after "	43·8776	
		·0468
Drying tube before combustion,	26·4294	
" " after "	26·4328	
		·0034
		·0502

This gives a composition of 97·85 per cent. of carbon, which is a pretty fair approximation to pure carbon. However, to determine whether or not this was not the case, some further experiments were tried. A small quantity of the carbon was placed on the platinum boat and burnt in oxygen without any of the gas being allowed to pass out of the apparatus, and the mixed gases so obtained transferred to a eudiometer, and the carbonic acid and oxygen absorbed. It was then found that a residue amounting to about 3 per cent. by volume of the carbonic acid was left unabsorbed by alkaline pyrogallate solution. This proved to be nitrogen. A blank experiment was done, but it gave only a minute bubble of nitrogen. Another experiment was performed with the following results:

Total volume, . . .	183·7°		
After absorption of CO_2, .	148·5°	CO_2 =	35·2
After " " O, . .	1·1°	O	147·4
		N	1·1

This plainly shows that nitrogen was present from some cause or another, and as every precaution was taken in transferring the gas from one vessel to another, and as the blank experiment showed nothing, I am inclined to believe that the carbon, or at least some portions of it, contained nitrogen chemically combined. The numbers above given are degrees on the eudiometer tube, and are not more than one-third of a cubic centimetre each. Their exact value was of no consequence in the experiment, and the tube was only calibrated by comparing one part with another, and not with an absolute measure.

From the fact that no diamond was found when nitrogen compounds were absent, and from the fact that the mixed product (for only a portion of the 14 mgrms. was clear diamond) contains nitrogen, I am inclined to believe that it is by the decomposition of a nitrogenous body, and not the hydrocarbon, that the diamond is formed in this reaction. The experiments are, however, too few, and the evidence too vague, to draw any conclusions, as there are even very few negative experiments from which anything can be learned, most of the results being lost by explosion. I intend, when my other work—which I laid aside for the diamond experiments—is finished, to begin a series of experiments on the decompositions of carbon compounds by metals, to find whether a more easily controlled reaction may not be discovered.

THE "GILLOTYPE" ENGRAVING PROCESS.

Extract from a notice in *Engineering*, of the recent Exhibition of Printing Machinery in London.

The so-called Gillotype engraving process is shown in its various stages by Messrs. A. S. Cattell & Co., of London, and since this process is an interesting one, and largely employed for the production of plates suitable for surface printing, it calls for some notice. A reversed drawing of the object to be engraved is first made on lithographic stone in the ordinary manner. From this drawing an impression is taken on a specially prepared transfer paper, just in the same way as an ordinary proof would be pulled from it, and the transfer is placed face downwards upon a highly-polished and perfectly flat zinc plate and exposed to considerable pressure, by which means a reverted picture is obtained on the plate, and a roller charged with a greasy ink is passed over it, the ink adhering to the lines on the plate, but to no other part of it. The plate is then placed in a rocking cradle containing a bath of highly diluted nitric acid, and the cradle is kept in constant gentle oscillation. The acid attacks all those parts of the metal not protected by the ink, and by eating it away produces a raised picture after some time of exposure; the rocking motion being necessary to remove the gas bubbles which form by the action of the acid on the zinc. It will be evident that without precaution being taken, the acid would very soon attack the sides of the lines thus raised and undermine them; to avoid this the plate is frequently taken out of the bath and rolled with the inked roller, after which it is slightly warmed to cause the ink to run down the sides of the raised lines, and so protect them. By these alternate operations of inking and eating away with acid the necessary depth for printing is gradually obtained, but the process is a slow one, requiring from three to eight hours, according to the nature of the work, and this again governs the strength of the acid used. Very fine work requires weak acid, and a long time for engraving, while coarser engraving can be bitten out more rapidly. The plates when completely engraved require some finishing and handwork, such as squaring up, trimming the edges, etc., and they are then mounted upon wood blocks to suit the height of the type with which they are

to be printed. The thickness of the zinc plates used is from $\frac{1}{12}$ to $\frac{1}{8}$ inch.

The same process of zinc engraving as above described can also be employed for the production of any subject, a picture of which is produced on the zinc in other ways than by lithography. Thus transfers from a steel or copper engraved plate or a photograph can be produced, the latter on a specially prepared zinc surface, or a sketch may be made on the zinc direct with lithographic ink or chalk.

Simple as this process appears, it requires considerable skill and care on the part of the operators to produce really good results, but some excellent specimens of blocks, as well as prints from the same, may be seen at the show, or at any time in the columns of this journal, our line engravings being prepared exclusively in this manner. The applications of this process are very various and widespread, and the advantages it possesses over line wood engraving are manifest. The simplest sketches, or the most complicated drawings covered with dimensions and writing, are produced with almost equal facility; fac-similes of ancient inscriptions, manuscripts, etc., can be photographed direct upon zinc, and require practically no hand labor, so that absolute accuracy is obtained. These are only a few applications, but are sufficient to show that the process is superior in many respects to the much older art of wood engraving, although it must always remain inferior to it where effects of color are required.

Volatile Power of Liquids.—Pictet gives a general equation, drawn directly from the mechanical theory of heat, which embraces all Regnault's equations of interpolation for all known volatile liquids; in other words, it gives the maximum tension of any given vapor at any given temperature. Let λ be the latent heat of volatilization at a temperature t; c the specific heat of the liquid; k the specific heat of the vapors; P the maximum tension of the vapors at temperature t; δ density of the vapors, varying according to the law of the co-volumes; $l\left(\frac{P^1}{P}\right)$ a specific integral deduced from the work done, in accordance with Mariotte's law. Then

$$l\left(\frac{P^1}{P}\right) = \frac{[\lambda^1 + (c-k)(t^1-t)]\,431 \times 274 \times 1{\cdot}293\,\delta\,(t^1-t)}{10333\,(274+t^1)(274+t)}$$

—*Comptes Rendus.* C.

LIGHTING ROOMS.

M. Javal, in a paper on public and private lighting, considered from the aspect of ocular hygiene (*Revue Scientifique*, Oct. 18, 1879, p. 361), treats of artificial lighting. He says, that a chandelier, carrying a million of wax lights, would not give an amount of light equal to sunlight. Even in a room, lit up in an unusually brilliant manner, the pupils are much more dilated than in full daylight; and this dilation explains the fatigue to the eyes produced by artificial light. Therefore, there is never too much, in fact never enough, artificial light, and prejudices, without any just foundation, are prevalent on this point. M. Javal recommends to persons suffering from certain optic defects, and who cannot work in the evening, two large lamps, which would obviate the fatigue of reading. Artificial light, also, excepting the electric and magnesium lights, contain much fewer chemical rays than daylight. All artificial spectra are very dull on the most refracted side; the chemical rays, the violets and the blues, there show a very low intensity. M. Bouchardat (*Revue Scientifique*, August 16, 1879, p. 148) has shown the dangers of violet and deep violet rays, on the authority of M. Regnauld's important work on the fluorescence of the media of the eye. The conclusion to be derived is that the flame light being poorer in chemical rays than sunlight, should be preferred by workers. In fact, M. Javal quotes the instance of a member of the Institute, whose fatigued vision would scarcely tolerate daylight, and who shut his shutters, and lighted his lamp, in order to work. M. Javal recommended him rather to work in daylight, with yellow spectacles, to destroy the chemical rays. Artificial light, on the other hand, considerably dilates the pupil, and renders the chromatism of the eye more sensitive, which is the reason that the light of day is to be preferred. The electric light is injurious, in a certain point of view; it contains a large quantity of chemical rays, which it would be easy to neutralize by giving a yellow tint to the globes. Nevertheless, neither the public, nor the experts, have complained, up to the present time, of the electric light; inconveniences only arise when the eyes are fixed for too long a time on a too powerful electric light. It is therefore advisable not to look too long at electric lights, and when this becomes a habit, the opacity of the globes now in use can be

diminished. In fine, all our systems of artificial light are insufficient; there is, then, no necessity to fear excess of light, since, on the contrary, artificial light is less penetrating than daylight. Gas, therefore, does not destroy the eyesight, it is the wavering and flickering of the flame, when there is neither globe nor chimney, which fatigues the sight; gaslight, with a burner protected by a globe, is excellent for it. M. Javal may well, then, say, with dying Göthe—"Light, more Light!"—*Sanitary Record.*

A NEW DEVELOPER IN PHOTOGRAPHY.

By Capt. W. de W. Abney, R.E., F.R.S., etc.

Some two years ago I began a series of experiments on developing agents, with a view of finding some one which would only act on the silver bromide which had been acted upon by light, and not on silver bromide as well. Now every one is aware that the ordinary alkaline development (except by a *tour de force*) acts upon silver bromide unless a restrainer or retarder such as gelatine or soluble bromide be at hand during the development. Except in the case of albumen beer plates in the form which I originally introduced, no collodion film, as far as I am aware, could be treated with pyrogallic acid and ammonia without a hopeless fog ensuing. In this case the albumen acted very much like gelatine does in the gelatino-bromide plates, and this process is therefore no exception to the rule. The most crucial test for a developer is to apply it to a plate coated with ordinary washed collodio-bromide emulsion, the film having no preservative. There are several organic substances which can be applied as preservatives, and which, when ammonia is applied, will cause a faint image to be developed; but intensity is always wanting. It would scarcely interest my readers to give the theoretical reasonings which led me to try a substance which is but little known, viz., hydro-kinone. It is sufficient to say that as a developing agent it is very perfect, and can be used in a collodion emulsion film without the slightest trace of restrainer or retarder; in other words, it requires no soluble bromide with it.

Hydro-kinone is a derivative from kinone, and, on the addition of certain metallic compounds to it, acts as a reducing agent. It is solu-

ble in alcohol, and in water to a large extent. The following experiments are worth a trial. Dissolve one grain in two drachms of water, and expose a collodio-bromide plate for half the time necessary with the ordinary alkaline developer, and apply this quantity of liquid with one drop of strong ammonia. The image will appear quietly, and show all detail, but on fixing will be rather too feeble; it will take silver intensification, however, perfectly. Double the quantity of hydro-kinone, and again develop a plate, and it will be found that the intensity is of a medium character, whilst by trebling it, it will be found that proper density is secured. With gelatine plates the same experiment may be repeated, a less quantity being apparently requisite to give proper printing density, than with collodion films. On fixing the plates they will be found perfectly free from any veil caused by a reduction where no reduction should be, and they will give brilliant prints.

It may be asked if the hydro-kinone has any advantage over the ordinary alkaline developer. I am inclined to think it has—in that the faintest trace of the action of light is made apparent, and is not destroyed by the soluble bromide. This should be a decided gain, and on testing it against ferrous oxalate (without bromide) in gelatine plates, it seems as if this were borne out. With collodion plates it has a decided advantage, and it may be worth a trial. A curious experiment is to prepare a collodion plate, wash it, and pour over it a solution of hydro-kinone and ammonia, and then expose in the camera; it will be found that development commences during the exposure; whereas such an attempt made with ordinary alkaline or ferrous oxalate developer would prove a failure. The great objection to the use of this compound is its price; it is expensive, but doubtless any demand for it would quickly reduce it to nearly the same price as pyrogallic acid. It is at present more a chemical curiosity than of any commercial use, but if it should prove to be a good developer, it would speedily find its way into the price list of manufacturing chemists at a more moderate rate than that at which it is now shown.—*Photographic News.*

Roof Varnish.—A varnish for roofs has been recently patented in Germany which is composed of 35 parts of clay slate, 30 parts mica slate and 35 parts rosin, all finely powdered and heated with 50 parts of tar.—*Bay. Ind. und Gewerbeblatt.* C.

MEAT BREAD.

M. Scheurer-Kestner has discovered the remarkable fact that the fermentation of bread causes the complete digestion of meat. He found that a beef steak cut into four pieces, and mixed with flour and yeast, disappeared entirely during the process of fermentation, its nutritive principles becoming incorporated with the bread. The meat would also appear capable of preservation for an indefinite period in its new state, for loaves of meat bread, made in 1873 have been submitted to the French Academy of Science, when not a trace of worms or mouldiness was observable. At the beginning of his experiments, M. Scheurer-Kestner used raw meat, three parts of which, finely minced, he mixed with five parts of flour and the same quantity of yeast. Sufficient water was added to make the dough, which in due time began to ferment. After two or three hours, the meat had disappeared, and the bread was baked in the ordinary manner. Thus prepared, the meat bread had a disagreeable, sour taste, which was avoided by cooking the meat for an hour with sufficient water to afterwards moisten the flour. The meat must be carefully deprived of fat, and only have sufficient salt to bring out the flavor, as salt, by absorbing moisture from the air, would tend to spoil the bread. A part of the beef may be replaced with advantage by salt lard, which is found to improve the flavor. The proportion of meat to flour should not exceed one half, so as to insure complete digestion. Bread made with a suitable proportion of veal is said to furnish excellent soup for the sick and wounded.—*Sanitary Record.*

Crystalline Form of Magnesium.—Des Cloizeaux has examined some beautiful crystals of magnesium, which were presented to the French Academy by M. Dumas. The crystals were obtained by sublimation and are of a white color, with the brilliancy of silver. Their faces are often curved and the edges blunt; the usual form is that of a regular hexagonal prism, terminated by a base which is a little less brilliant than the lateral faces. The edges of the base are often replaced by an annular truncation, the combination of which with the faces of the prism recalls that of tellurium crystals. The culminating angle is more acute than in the other rhombohedral metals, arsenic, tellurium, antimony and bismuth. The crystals are very malleable and sectile, but without visible cleavage.—*Compt. Rend.* C.

Earthen Filtering Plates.—G. W. Reye & Sons, of Hamburg, make filtering plates from a mixture of one part of gypsum with three parts of imperial earth in water. They can be purified after using by washing or burning. When impregnated with carbolic acid they also become useful as disinfectants.—*Dingler's Journal.* C.

Electric Sun.—Lontin has been exhibiting in the building of the Industrial Exhibition in the Champs Elysées, Paris, a circular electric light, formed by four voltaic arches. He uses four carbons placed radially, the two which are in the same diameter being connected with the same pole, so that an arch extends from each of the carbons to each of its neighbors. These four arches unite to form a complete circle and produce a light of extraordinary brilliancy.—*Dingl. Jour.* C.

Dissociation of Metalloids.—Pictet proposes a plan which he thinks might effect the dissociation of metalloids, but which is too costly for him to undertake at his own expense. It consists of a parabolic mirror, with a section normal to the sun's rays which should have at least 35 metres (41·86 sq. yards) of surface. He estimates that this would give a heat equivalent to 1000 calories (2200 thermal units) per minute, and that such a heat would probably be sufficient to decompose any of the metalloids which are really compound bodies.—*Les Mondes.* C.

An Intensified Electro-Magnet.—Dr. Stone recently exhibited before the Physical Society a very interesting electro-magnet of novel construction, and based on a principle which will probably be applied with advantage in the construction of electro-magnets for dynamo-electric machines and telegraphic apparatus. It is known that electro-magnets enclosed in jackets of soft iron are far more powerful than when the copper coil of wire is unenclosed. In fact, the iron jacket, like the second armature or diaphragm in M. Ader's form of Bell telephone recently described by us, has the effect of exalting the magnetic power of the poles. Dr. Stone does not employ a soft iron jacket, but instead of using copper wire to wind the bobbins he uses best charcoal annealed iron wire about $\frac{1}{8}$ in. in diameter, Four wires are wound on in parallel circuits, and the current is split up among them in "multiple arc." They are insulated from each other by paraffine wax. By this felicitous arrangement the lifting power of Dr. Stone's large magnet is, with a battery of four or five Bunsen cells, increased fourfold.—*Engineering.*

COMMUNICATIONS.

U. S. NAVAL OBSERVATORY,
Washington, D. C., June 15, 1880.

Committee on Publication of the Franklin Institute Journal:

GENTLEMEN:—Some months ago I had occasion to investigate the strength of a particular class of gearing, and now it seems desirable to extend the investigation to all kinds of gearing. The numerical values of the coefficients in my formula can only be determined from wheels in actual use, which are known to be working up to their full capacity. The data required are:

1. The material composing the wheel.
2. Its diameter at the pitch line.
3. The width of its face.
4. The number of its teeth.
5. Its pitch.
6. The number of revolutions it makes per minute.
7. The number of horse-power transmitted by it; or, the pressure in pounds at its pitch line.
8. A statement of the kind of machinery it drives.

These data will be of no value unless it is known that the wheel is working up to its full capacity, and in every case the reasons for supposing that it is doing so should be stated.

The method of determining the pressure at the pitch line should also be stated. If the wheel transmits the full power of an engine, its actual, not its nominal, horse-power should be given. In such cases the power should be determined from indicator diagrams, if possible. When that cannot be done the following particulars should be specified concerning the engine:

1. Condensing or non-condensing.
2. Diameter of piston.
3. Length of stroke.
4. Number of revolutions per minute.
5. Pressure of steam.
6. Point at which the steam is cut off.

May I appeal to your readers to furnish me such information? If